Australia Pacific LNG Project

Volume 5: Attachments

Attachment 20: Marine Ecology Technical Report – LNG Facility

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Executive Summary

Australia Pacific LNG Limited proposes a project which comprises the development of coal seam gas (CSG) fields, the construction of a gas pipeline, together with the construction of a liquefied natural gas (LNG) plant and associated facilities to export the gas to international markets. This report focuses on the construction of the pipeline in the marine environment. The pipeline is proposed to cross the wetlands of Targinie Creek on the mainland and then across The Narrows to a landing on Curtis Island just south of Laird Point. The LNG plant is located just south of Laird Point on Curtis Island.

This report describes the marine environmental values in Port Curtis and assesses the potential impact on the marine environment of constructing and operating of an LNG plant at the proposed location.

Broadly, the key features of the marine environment in Port Curtis are:

- Extensive saltpan/saltmarsh, seagrass and mangrove habitats that provide important nursery habitat for juvenile fish and prawns, and support fisheries production. The seagrass is also a food source for dugong.
- Nesting and feeding habitat for marine turtles. There is a medium density flatback turtle rookery at Southend on Curtis Island.
- Habitat for inshore dolphin species including the endemic Australian snubfin dolphin, the Indo-Pacific humpback dolphin and the inshore form of the bottlenose dolphin.
- Although the seabed is dominated by unvegetated sedimentary environments, natural rocky reef habitat occurs, and there is artificial hard substrata including jetty piles and rock walls.
- An assemblage of macrobenthic infauna that is dominated by filter feeding organisms, with species richness and abundance that is lowest on fine muddy substrates in intertidal areas, and greatest in the coarse sandy sediments that predominated in the deeper channels of the estuary.
- Utilisation for commercial and recreational fishing
- Water quality that is generally high but influenced by tidal state and input from river systems. It is identified the Fitzroy River catchment is a source of elevated dissolved metals (nickel and to a lesser extent copper) that occur in The Narrows.

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1. Introduction

This report addresses potential environmental issues and impacts to the marine ecology for the Australia Pacific LNG Project, specifically those related to the construction and operation of a Liquefied Natural Gas (LNG) plant near Laird Point on Curtis Island.

Australia Pacific LNG Pty Limited (Australia Pacific LNG) proposes to develop a project which enables the creation of a world scale, long-term industry in Queensland, utilising Australia Pacific LNG's substantial coal seam gas resources in Queensland. Australia Pacific LNG holds significant interests in less developed areas across the Walloons Fairway in the Surat Basin, which together with the Talinga coal seam gas fields constitutes the Walloons gas fields development area

The LNG plant will include up to four LNG trains with an installed capacity of 16-18 Mtpa and associated wharf and marine off-loading facilities to be located at Laird Point within the Curtis Island Industry Precinct of the Gladstone State Development Area. The LNG plant will utilise ConocoPhillips' proprietary Optimised Cascade® technology.

This report describes:

- Reclamation of intertidal and shallow sub-tidal areas for the purpose of constructing the LNG plant and associated infrastructure including the Material Offloading Facility (MOF)
- Operation of vessels, in particular fast ferries
- Discharges to the marine environment from the LNG plant including that from the desalination, stormwater and sewage systems

Dredging activities associated with the deepening and widening of existing shipping channel, swing basins and berth pockets with the Gladstone Port area are not included in this report as they are being considered as part of the Port of Gladstone Western Basin Dredging and Disposal Project undertaken by the Gladstone Ports Corporation (GPC).

Issues associated with sediments are also considered in the Environmental Impact Statement (EIS) for the Western Basin Dredging and Disposal Project Coastal process modelling is covered in another technical report in this EIS (refer to Attachment12).

2. Existing environment

Biogeographically, Port Curtis falls within the Shoalwater Coast bioregion as defined in the *Interim Marine and Coastal Regionalisation for Australia* (IMCRA Technical Group, 1998), which includes the coastal and island waters from Mackay south to Baffle Creek. This inshore coastal region comprises large bays with very large tidal ranges (up to six metres), large coastal islands, mostly sedimentary substrates, and relatively low rainfall. Port Curtis has areas that are largely unimpacted by human activity as well as areas that are highly modified by port developments and various industries.

The description of the existing environment is principally drawn from peer-reviewed literature and the latest and most relevant technical reports. Augmenting this was non-invasive and non-manipulative field work specifically at the proposed locations where the project is to be undertaken.

2.1 Marine parks, wetlands and World Heritage areas

The proposed location for the LNG plant is near Laird Point on the western side of Curtis Island. It is situated within the Gladstone Port Limits, however all of the Port waters below the mean low water mark lie within the Great Barrier Reef World Heritage Area. The World Heritage values of the Great Barrier Reef World Heritage Area are described in Appendix A.

Prior to 2004, four Queensland marine parks existed in the Great Barrier Reef Region: the Mackay/Capricorn Marine Park; Townville/ Whitsunday Marine Park; Trinity Inlet/ Marlin Coast Marine Park; and the Cairns Marine Park. In 2004 these marine parks were amalgamated into the Great Barrier Reef Coast Marine Park with additional areas added. It now includes the rivers, creeks and mangrove areas that formed parts of these four marine parks, together with intertidal areas of the coastline that border the Great Barrier Reef Marine Park.

Figure 2.1 shows the site plan for the LNG facility with the context of marine environment also outlined in the figure. The Narrows area (Figure 2.1) was previously included as part of the Mackay/Capricorn Marine Park but is now included in the Great Barrier Reef Coast Marine Park (in Schedule 3 of the *Marine Parks (Great Barrier Reef Coast) Zoning Plan 2004* as area QI HP-22-01). The Narrows is the 20,903 ha passage that separates Curtis Island from the mainland and is one of only five tidal passages within Australia. Habitat types within the wetland include saline coastal flats, mangrove forest, intertidal sand and mud flats, seagrass beds and open marine and estuarine waters. The Narrows is zoned as a habitat protection zone and the southern boundary of this zone is a straight line from Laird Point to Friend Point. The objectives to be achieved in a habitat protection zone are:

- To provide for the conservation of the areas of the marine park within the zone through the protection and management of sensitive habitats that are generally free from potentially damaging activities, and
- To provide opportunities for reasonable use of the areas.

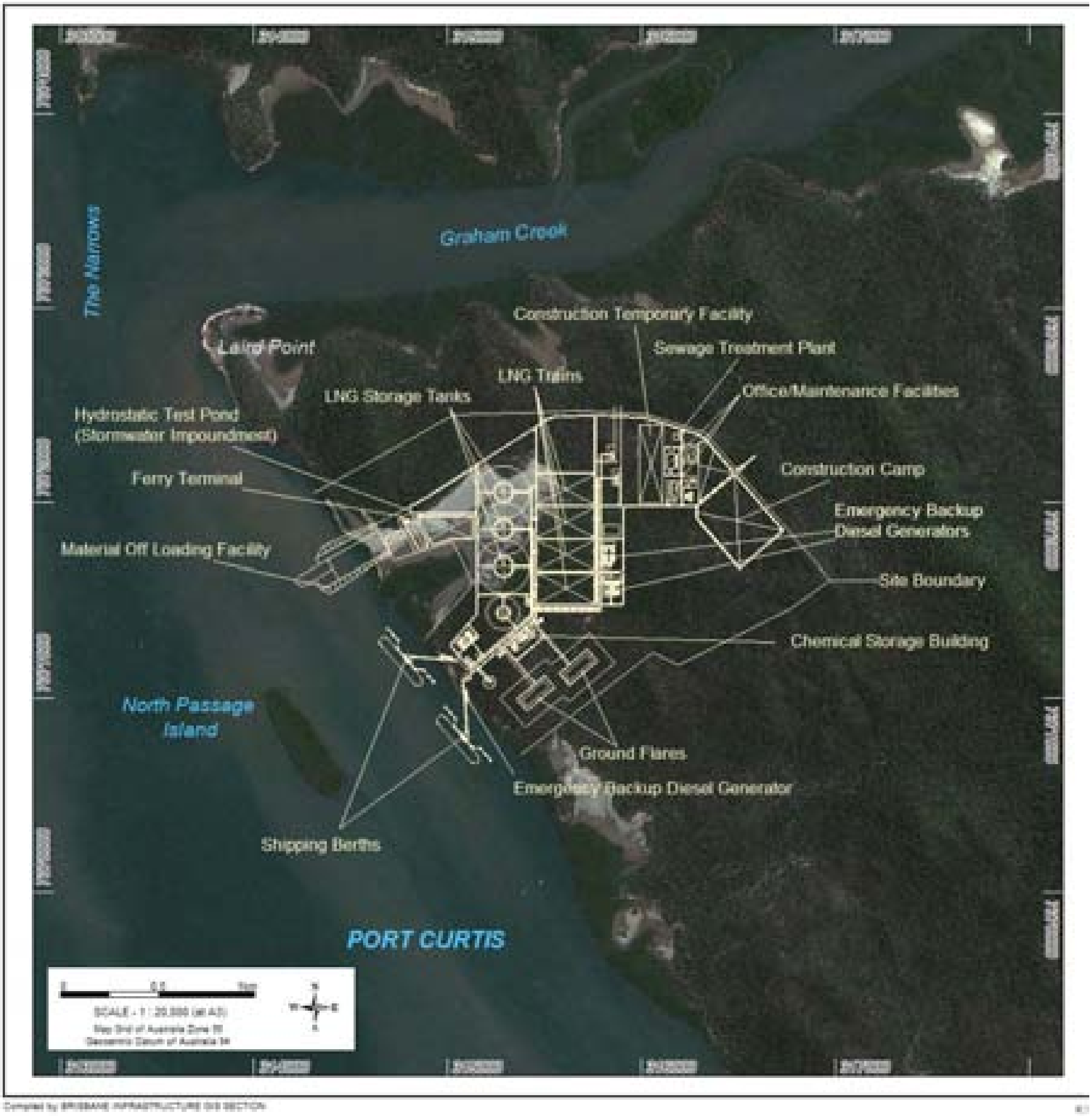

Figure 2.1 Indicative site plan for the LNG facility

Ramsar wetlands are not located within or adjacent to the proposed development site. The closest Ramsar wetlands are Corio Bay and Shoalwater Bay, which are approximately 150km north of the site. Laird Point is within the Curtis Island Nationally Important Wetland (QLD021).

The nearest declared fish habitat areas are the Fitzroy River which includes large parts of the northern and north-western parts of Curtis Island (FHA-072), Colosseum Inlet (FHA-037) and Rodds Harbour (FHA-036). These are approximately 23km, 35km and 50km respectively, from the proposed LNG plant.

Extent and condition of marine habitats

The primary environmental features of interest in the vicinity of the proposed development site are the seagrass meadows, mangrove and saltmarsh areas. These vegetated habitats contribute significantly to the high primary productivity of estuarine areas. They also provide structurally complex habitats that

maximise food availability and minimise predation for fish, prawns and crabs (Halliday and Young, 1996; Thomas and Connolly, 2001; Heck et al., 2003).

Rocky intertidal and shallow sub-tidal environments also exist in the study area and these are important foraging areas for various fish species. Man-made structures such as jetties and seawalls also provide additional hard substrata within the Port Curtis region. Extensive un-vegetated intertidal banks also occur in the area around Laird Point, and these banks also provide foraging opportunities for fish at high tide and shorebirds at low tide.

2.1.1 Seagrass

The seagrass beds of the Port Curtis region have been extensively investigated and mapped by Rasheed et al. (2003), Taylor et al. (2007) and Chartrand et al. (2009). Approximately 20% of the intertidal (7,246 hectares) and sub-tidal beds (6,332 hectares) of Port Curtis are covered by seagrass. Generally the area of the seagrass bed and seagrass biomass peaks in later spring and summer and is lowest over winter (McKenzie 1994; Lanyon and Marsh 1995). The seagrass surveys are undertaken when the area and biomass of the seagrass beds in Port Curtis is approaching, or at, its seasonal maximum.

Table 2.1 describes the key parameters (area and above ground biomass) of the main seagrass beds in the northern part of Port Curtis and the location of these beds are described in Figure 2.2. Ongoing monitoring of six of the seagrass meadows between 2002 and 2008 has shown that the area of intertidal seagrass beds has generally remained the same, while the area of the two sub-tidal seagrass beds that are the subject of regular monitoring (Western Basin 2 and South of Fisherman's Landing 2) both showed significant variations. In particular the area of sub-tidal seagrass at the South of Fisherman's Landing 2 site fell significantly in 2007 before showing some sign of recovery in 2008, and the area of sub-tidal seagrass beds at the Western Basin 2 site fell significantly in 2005 before showing clear signs of recovery over the next three years (Figure 2.3).

The principal driver of seagrass change in Port Curtis is local climate conditions. High rainfall events and high inflows of freshwater may result in seagrass declines as a result of inputs from nutrients, sediment, herbicides and reduced salinity. These declines are generally reversed with the associated nutrient inputs enhancing seagrass growth (Waycott et al. 2007).

A small seagrass bed consisting of aggregated patches of *Zostera capricorni* occurs in the vicinity of the proposed LNG plant.

Table 2.1 Description of Seagrass Beds in the northern part of Port Curtis (modified from Rasheed et al. 2003)

General location	Seagrass species and general description	Biomass (g/dw/m-2)	Seagrass area (hectares)
Laird Point (30)	Aggregated patches of Zostera capricorni of light cover.	2.9 ± 1.5	14.9 ± 1.3
South of Laird Point (32)	Isolated patches of Z. capricorni of light cover.	N/A	2.4 ± 0.3
Passage Islands 1 (31)	Aggregated patches of Z. capricorni of light cover with Halophila ovalis	0.9 ± 0.2	40.0 ± 2.6
Passage Islands 2 (35)	Aggregated patches of Z. capricorni of light cover with H. ovalis	0.7 ± 0.2	22.1 ± 2.0
Passage Islands 3 (33 & 34)	Aggregated patches of moderate H. ovalis with Z. capricorni	1.0 ± 0.5	10.1 ± 0.8
Western Basin 1 (including Friend Point) (8)	Aggregated patches of Z. capricorni of light cover with H. ovalis, H. spinulosa and H. decipiens	2.1 ± 0.3	269.1 ± 11.3
Western Basin 2 (9)	Aggregated patches of H. decipiens with H. ovalis.	0.9 ± 0.3	268.3 ± 14.9
South of Fishermen's Landing 1 (6)	Aggregated patches of Z. capricorni of light cover with H. ovalis, H. decipiens and H. spinulosa	1.1 ± 0.1	464.0 ± 12.9
South of Fishermen's Landing 2 (7)	Aggregated patches of H. decipiens	0.9 ± 0.2	72.6 ± 11.3
Wiggins Island 1 (4)	Aggregated patches of Z. capricorni of light cover with H. ovalis	0.8 ± 0.4	35.8 ± 1.7
Wiggins Island 2 (6)	Aggregated patches of Z. capricorni of light cover with H. ovalis and Halodule uninervis	1.4 ± 0.3	149.8 ± 2.5

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Seagrass distribution digitized from: Rasheed, M.A., Thomas, R., Roelofs, A.J., Neil, K.M. and Kerville, S.P. 2003. Port Curtis and Rodds Bay seagrass and benthic macro-invertebrate community baseline survey, November/December 2002. QDPI Information Series QI03058 (DPI, Cairns).

Satellite imagery (GeoEye-1 on 24 March 2009) AAM Hatch 2009

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Figure 2.2 Locations of seagrass beds in the northern part of Port Curtis

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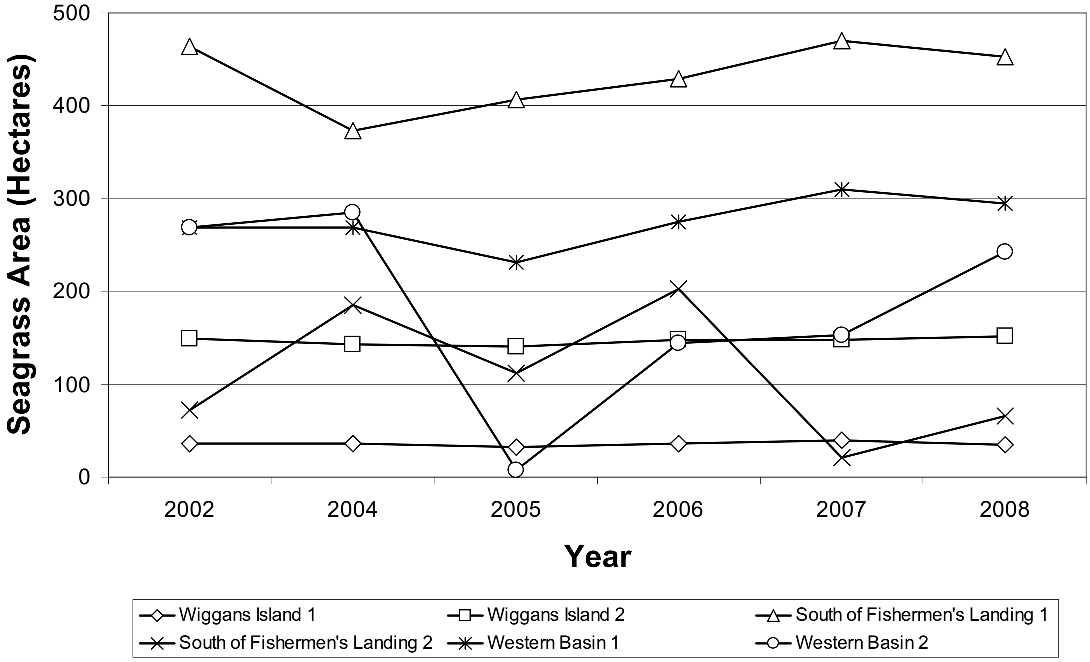

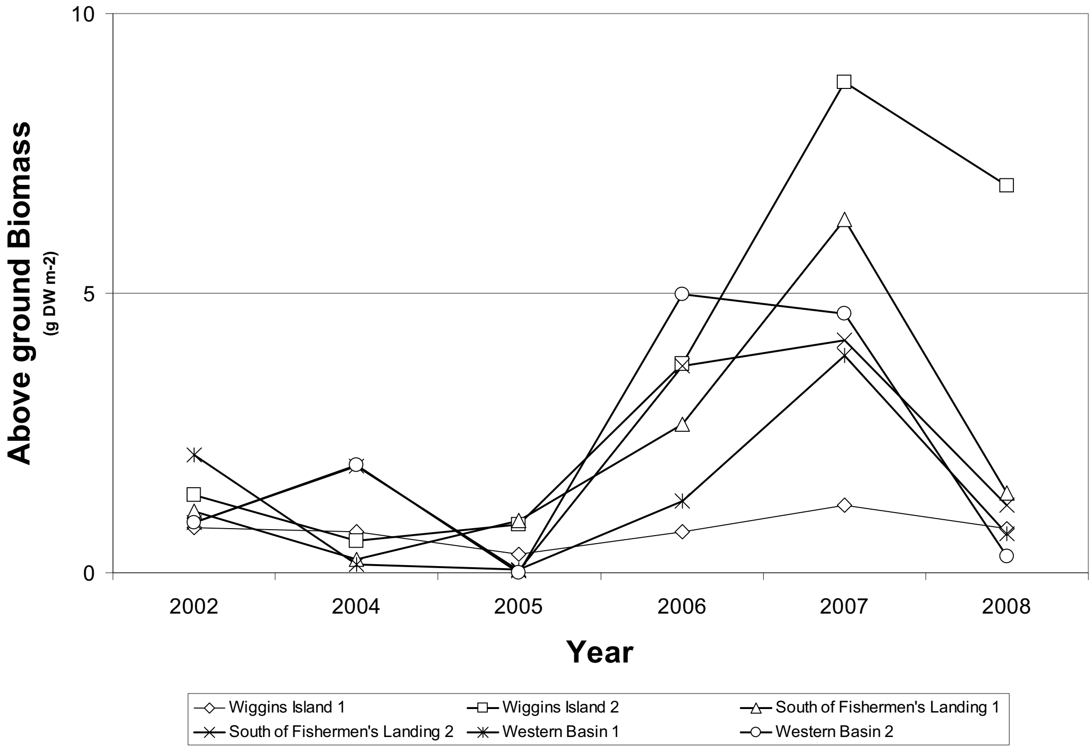

Figure 2.3 Seagrass area (top) and above ground biomass (below) of six seagrass beds in the northern Port Curtis area between 2002 and 2008 (modified from Chartrand et al. 2009)

2.1.2 Mangroves and saltmarsh

Mangroves provide a structurally complex habitat that can provide food and protection directly for juvenile fish and invertebrates and a source of carbon that may be exported by the tide to other areas and contribute to the food web elsewhere in a region (Manson et al. 2005; Meynecke et al. 2008). Extensive mangroves extend along the coastline from the Gladstone city precinct and into the Narrows and these have been surveyed by Danaher et al. (2005). Within the Gladstone region it is estimated that there are 3875 patches of mangroves with an area of 203km^2 and a perimeter of 4855 km (Manson et al. 2005). However, Duke et al. (2003) reported a regional loss of almost 40% of mangrove area in Port Curtis between 1941 and 1999. Fourteen species of mangroves are reported from the Port Curtis region (Saenger, 1996):

- Club mangrove (Aegialitis annulata)
- River mangrove (Aegiceras corniculatum)
- Orange mangrove (Bruguiera exaristata)
- Large-leafed orange mangrove (Bruguiera gymnorrhiza)
- Blind-your-eye mangrove (Excoecaria agallocha)
- Black mangrove (Lumnitzera racemosa)
- Myrtle mangrove (Osbornia octodonta)
- Red mangrove (Rhizophora stylosa)
- Cannonball mangrove (Xylocarpus granatum)
- Cedar mangrove (Xylocarpus moluccensis)
- Yellow mangrove (Ceriops tagal)
- Grey mangrove (Avicennia marina)
- Mangrove fern (Acrostichum speciosum)
- Holly leaf mangrove (Acanthus ilicfolius).

Port Curtis represents the southern limit of the distribution of two of these mangrove species (orange mangrove and cedar mangrove). The mangrove assemblage in Port Curtis while diverse is dominated by red mangrove with lesser amounts of yellow mangrove and grey mangrove also present. Red mangrove tends to dominate the seaward edge of the assemblage while yellow mangrove and grey mangrove are generally more abundant on the landward edge. The mangrove assemblage is considered to be in a healthy state at the proposed development site and in Port Curtis in general.

Also present in the Curtis Coast region are salt pans, which are largely bare, but contain patches (or isolated plants) of salt marsh species such as *Sueda* spp., *Sarcocornia quinqueflora* and *Sporobolus virginicus*. While saltmarsh habitats receive only intermittent tidal inundation, fish can extend many hundreds of metres into salt marsh habitats on spring tides, and their importance for fisheries production is well documented. Important commercial and recreational fish species such as yellowfin bream (*Acanthopagrus australis*) and various species of mullet are well known to frequently utilise salt marsh habitat in Queensland as juveniles (Morton et al. 1987; Thomas and Connolly 2001; Sheaves et al. 2007) and this is discussed further in Section 2.8.

2.1.3 Rocky reefs and rocky shores

Intertidal rocky shores occur at a number of locations in the Port Curtis region including in the vicinity of the proposed LNG plant and associated marine infrastructure. These rocky shores are best described as a “rubble field” with significant oyster cover, and other macro-invertebrates that associate with oyster cover, in particular the oyster borer (*Morula marginalba*).

Rasheed et al. (2003) also identified rubble reef areas in the deep channel area from the vicinity of Graham Creek to Fishermen’s Landing which contained medium density cover (>15% of the area surveyed) of bivalves, ascidians, bryozoans and hard corals. Other such areas of reef habitat are located in the vicinity of Hamilton Point.

2.2 Marine habitats within the proposed development footprint

2.2.1 Intertidal habitats

Field investigations of the habitats within the proposed development footprint were undertaken during June 2009. Intertidal areas were visually inspected and described using a drop video camera that was systematically deployed across a number of pre-determined locations across the development footprint.

The location for the Australia Pacific LNG Facility at Laird Point is principally saltpan which is inundated on spring tides. The development location surrounds a large stand of mangroves that extends between 120m and 200m from a small tidal creek that drains into Port Curtis. This stand of mangroves contained red mangrove, yellow mangrove, grey mangrove and blind-your-eye mangrove. The LNG facility has been designed such that this area of mangrove will be retained. While the saltpan is largely unvegetated, isolated plants of various saltmarsh species are present as are a number of small isolated mangrove trees (Figure 2.4). The landward edge of the saltmarsh contains small “stunted” mangroves, and isolated patches of mangroves also occur along a number of natural drainage lines within the proposed development site, and small isolated mangrove trees occur in a number of locations. Crab burrows (most probably *Uca* spp.) were associated with the isolated mangrove trees. Saltmarsh species recorded include common samphire (*Sarcocornia quinqueflora*), marine couch (*Sporobolus virginicus*) and spiny sea rush (*Juncus kraussii*) (Figure 2.5).

The seaward edge of the proposed development site (Port Curtis) consists of an upper area of sandy beach extending into a predominantly rocky shore which transitions to mud flat in the lower part of the shore (Figure 2.6). Taylor et al. (2007) identified that a small area of seagrass (principally *Zostera capricorni*) occurs on these mudflats.

Figure 2.4 Views of the proposed LNG Facility site near Laird Point showing the largely unvegetated saltpan. The aspect is looking towards the mangrove stand in the centre of the saltpan area. Evidence of crab burrowing activity in association with isolated mangrove trees is shown in the bottom picture.

Figure 2.5 Examples of saltmarsh plants - the common samphire (top and bottom) and marine couch (top).

Figure 2.6 Rocky shore with mangroves (top) and boulders transitioning into mudflats.

2.2.2 Sub-tidal habitats

A drop camera video recording system (Outland Technology Inc.) was used at selected sub-tidal sites in the vicinity of the proposed LNG plant to provide visual information on typical seabed features. The survey points are described in Figure 2.7. Video information was recorded directly onto DVD and video captures obtained.

The sub-tidal area in the vicinity of the proposed LNG plant is principally bare substrate. A high amount of unconsolidated shell and rubble material was present at many of the sites surveyed. Some macroalgae was present attached to shell and rubble at a number of locations. Evidence of bioturbation was largely absent. No hard coral was present and there was no reef structure that afforded any vertical relief, although isolated epifauna individuals (e.g. gorgonians) were present.

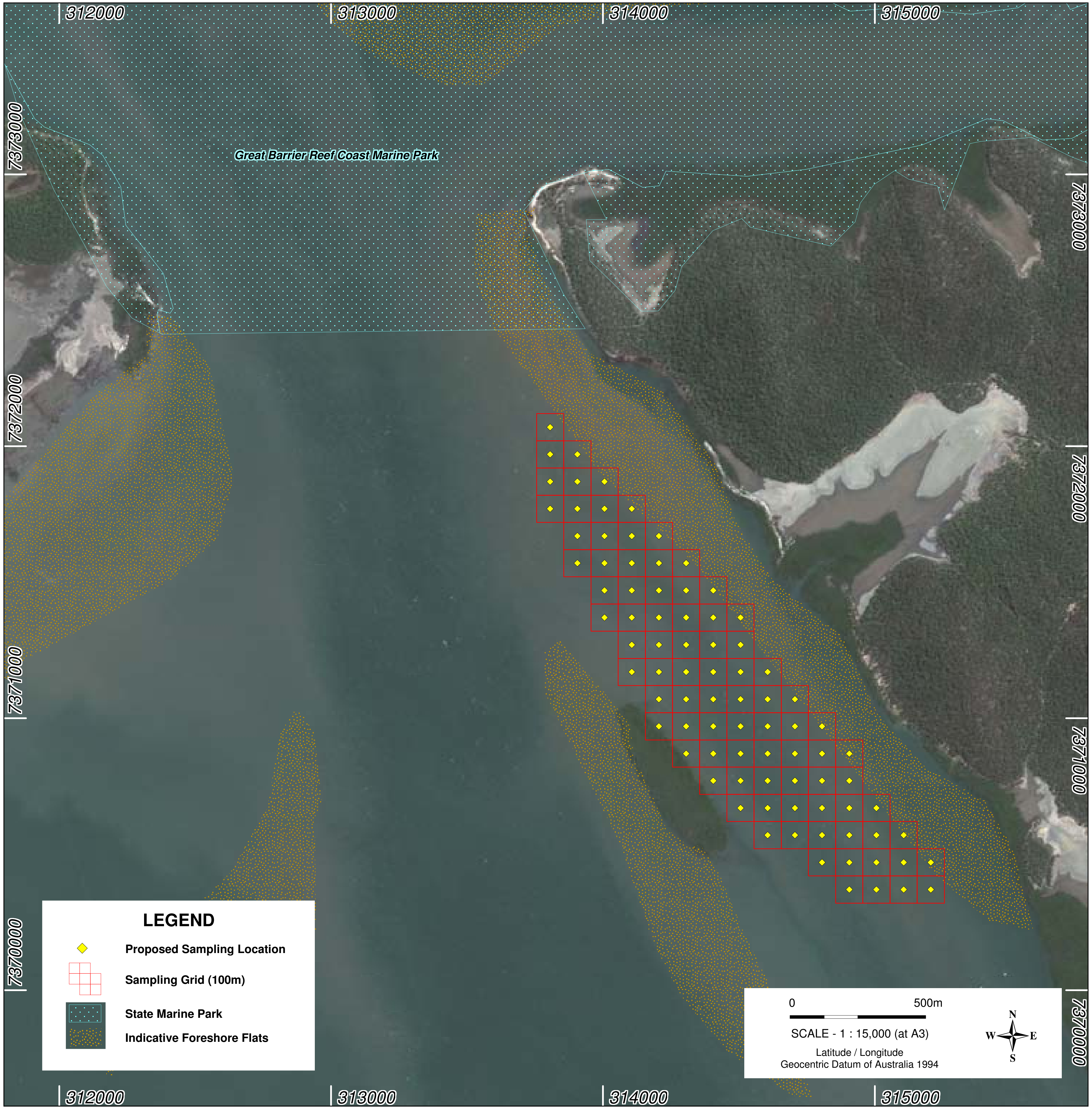

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Figure 2.7 Drop camera video survey points

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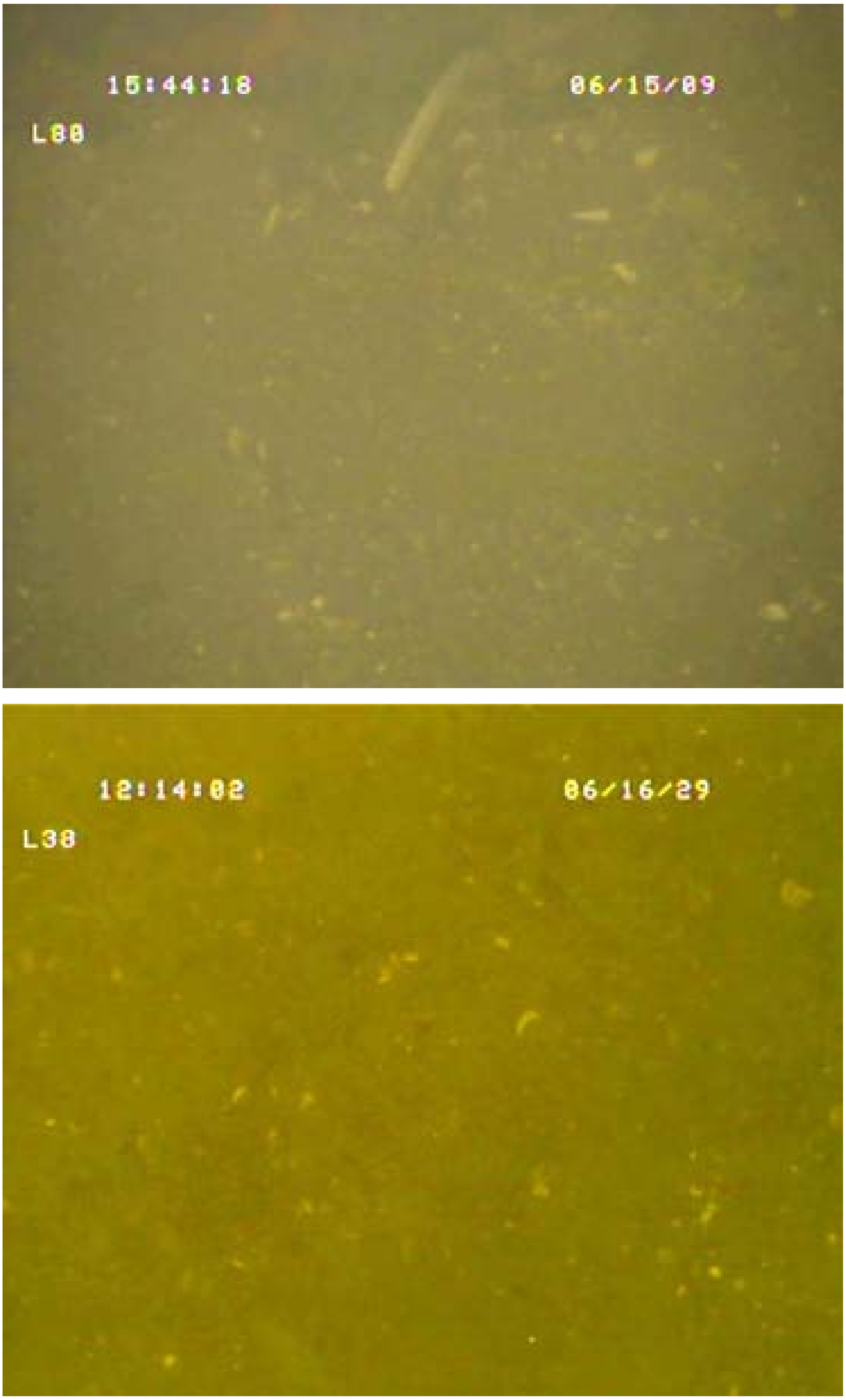


Figure 2.8 Examples of the seabed in the vicinity of Laird Point

2.3 Water quality

2.3.1 Environmental values

The Queensland Water Quality Guidelines default to the Schedule 1 of the *Environmental Protection (Water) Policy 1997* for describing the environmental values within different regions of Queensland. Currently however, there are no environmental values (EVs) or water quality objectives (WQOs) specifically established for Port Curtis, in accordance with Schedule 1 of the *Environmental Protection (Water) Policy 1997*. Therefore, the environmental values are those identified in the ANZECC/ARMCANZ (2000) guidelines, the State Coastal Management Plan (EPA/QPWS, 2002) and the Curtis Coast Regional Coastal Management Plan (EPA/QPWS, 2003). Environmental Values are particular values of the environment important to maintain the health of the ecosystem, public benefit, welfare, safety or health. These values require protection from the effects of pollution, waste discharges and deposits. The following environmental values are recognised:

- Aquatic ecosystems
- Primary industries (irrigation and general water uses, stock drinking water, aquaculture and human consumption of aquatic foods)
- Recreation and aesthetics
- Drinking water
- Industrial water (no water quality guidelines are provided for this environmental value)
- Cultural and spiritual values.

All water resources are usually subject to one or more of the above environmental values. Port Curtis has no EVs established, so a conservative approach has been taken and it is therefore assumed that all of these environmental values are applied to the resource by default, with the exception of drinking water. In addition, the State Coastal Management Plan and Curtis Coast Regional Coastal Management Plan recognise a number of other environmental values which need to be protected from a water quality management perspective. These include habitat for native and migratory animals, habitat for native plants, nursery habitat, fishing and localities for maritime infrastructure.

2.3.2 Existing water quality

Port Curtis is recognised as a well mixed estuary and traditionally assumed to also be well flushed and readily dispersed to the offshore environment. A study by Apte et al. (2005) however, showed that while water circulation within the Port Curtis estuary was strong, material had difficulty in discharging from the estuary. It was found that the time for the total mass of water to exchange by two thirds of its original mass, was approximately 19 days. Although metal contaminant concentrations are below water quality guidelines (Apte et al. 2005; Jones et al. 2005), the limited flushing of the estuary may potentially have important water quality implications in the estuary, when metals are resuspended into the water column from dredging, reclamation and spoil disposal, and dewatering activities. For example, marine organisms in the estuary have previously been exposed to higher metal concentrations, compared to those in pristine environments and showed evidence of bioaccumulation of these contaminants (Andersen et al. 2005; Apte et al. 2005; Jones et al. 2005).

Water quality studies in Port Curtis have generally been consistent in identifying that water quality conditions within Port Curtis are good, although strongly influenced by tidal state. Water quality within

Port Curtis appears to be strongly correlated with tidal state, where low tides generally exhibiting reduced water quality conditions. The physio-chemical water quality parameters are described in Table 2.2.

Table 2.2 Physico-chemical WQ Parameters (EPA data 1996-2006)

	Gladstone Harbour water quality parameters				
	Minimum	**20th percentile**	**Median**	**80th percentile**	**Maximum**
Temperature °C	17.7	22.5	26.2	29.2	33.9
Conductivity mS/cm	29.9	52.7	55.0	56.6	60.5
Salinity[1] ppt	18.5	34.7	36.5	37.6	40.6

[1] Derived from Temperature and Conductivity (note Conductivity @ 25ºC). Parts per thousand (ppt)

Temperature, conductivity and salinity values were generally within the range expected for inshore marine waters. Minimum salinity values reported may be representative of freshwater inputs, likely from the adjacent estuaries, including the Calliope and Fitzroy Rivers. The pH within Port Curtis was reported in the Gladstone Ports Corporation Environmental Impact Statement (GPC, 2009), within the range of pH 7 to pH 8.5, and generally around pH 8, which is indicative of inshore marine waters. Again, the lower values would have been representative of freshwater/ estuarine influences. Total suspended solids and nutrients were considerably more variable, and on many occasions were reported to exceed QWQG (2006) and ANZECC/ARMCANZ (2000) guidelines (GPC, 2009).

The pH and temperature were generally uniform throughout the water column, within the Port Curtis estuary (BMT WBM, 2009), however isolated elevated temperatures with a maximum differential of 8.2 ^{0}C occur in the vicinity of the cooling water discharge of the Gladstone Power Station, which discharges into the Calliope River (Saenger et al., 1982). This finding is supported by the monthly water quality measurements taken during baseline data collection for the GPC EIS, where temperature and pH were almost always homogeneous through the water column (GPC, 2009). A slight change in temperature (thermocline) was however, detected in May 2009 sampling, where there was a 0.5 ^{0}C difference in bottom waters compared to the mid and upper water column (GPC, 2009).

Fixed site turbidity monitoring undertaken during baseline studies for the GPC EIS reported median turbidity in deep waters during the dry season ranging from 3 to 9 NTU and 95th percentiles from 11 to 35 NTU. Monitoring at shallow water sites reported median turbidity levels of 9NTU and 95th percentiles of 30 to 90 NTU. Median turbidity in shallow water sites during the wet season were considerably higher, ranging between 10 and 23 NTU, compared to dry season monitoring.

Within the estuary, common contaminants that have been assessed include various metals, fluoride, cyanide and tributyltin (TBT). Metals within the Port Curtis estuary have consistently been recorded as occurring below ANZECC/ARMACANZ (2000) guidelines (Apte et al. 2005; Jones et al. 2005). However, metal concentrations, particularly dissolved copper, nickel, lead and zinc are elevated in comparison with pristine coastal water sites in Australia (Apte et al. 2005). In particular copper and nickel have elevated concentrations in The Narrows and elevated concentrations of lead and zinc are present in Port Curtis. Apte et al. (2005) provide a comparison of metal concentrations from the Port Curtis estuary with those at various locations in nearby marine waters (Table 2.3).

Apte et al. (2005) concluded that, based on the distribution of copper and nickel concentrations in The Narrows, these contaminants are likely to be representative of naturally occurring concentrations. In

comparison, lead and zinc concentrations in Port Curtis are considered most likely to be influenced by anthropogenic inputs.

Water from the Fitzroy River is a source of dissolved metals to the region and, under certain conditions, may flow into The Narrows and ultimately Port Curtis. Of particular note, is that the Fitzroy River contains elevated concentrations of nickel, and to a lesser extent copper, which may be influencing observed metal concentrations reported in The Narrows (Apte et al, 2006). The Narrows until recently was thought to be a relatively pristine area. Given the results of recent sampling, which have indicated elevated metal concentrations, it has been hypothesised that The Narrows may potentially act as a source of contaminants into Port Curtis (Apte et al, 2006). Interestingly monthly baseline water quality sampling for the (GPC, 2009) EIS, showed that all of the metals tested, with the exception of cadmium concentrations in May 2009, were within ANZECC/ARMCANZ (2000) trigger limits.

TBT is a contaminant of concern in Port Curtis and has been identified as occurring in concentrations above trigger levels within the water column, particularly around Fisherman's Landing and the mid and southern harbour (Jones et al. 2005). However, in comparison, levels are much lower than reported in ports around Australia (Andersen 2004). TBT has been found to have bio-accumulated in the biota of Port Curtis (oysters, mud whelks and mud crabs), but is expected to decrease over the coming years, as TBT continues to be phased out as an anti-foulant on ships worldwide (Andersen et al., 2004).

Table 2.3 Concentration of trace metals in nearby marine waters (Apte et al. 2006)

Location	Metal Concentration, ng/L				
	Cd	Cu	Ni	Pb	Zn
Port Curtis (average)	6	496	407	76	163
The Narrows (average)	7	512	536	21	124
Central Queensland Coastal waters (average)	1	42	147	13	34
Lower Fitzroy River (saline)	8	672	1030	21	118
NSW coast	2.4	31	180	9	<22

2.3.3 Level of ecosystem protection

For the purposes of describing water quality, Port Curtis can be described as "slightly to moderately" disturbed. ANZECC/ARMCANZ (2000) guidelines for toxicants in aquatic ecosystems commonly apply a 95 percent protection level to ecosystems that are classified as "slightly to moderately" disturbed. Furthermore, the Guidelines recommend that trigger values for slightly to moderately disturbed systems also be applied to highly disturbed ecosystems wherever possible. This addresses the reality of the "continuum of disturbance" whereby the specified levels of protection are essentially arbitrary classifications and their application can be such that they can be used to set 'aspirational targets'.

2.3.4 Water quality guidelines

The ANZECC/ARMCANZ (2000) guidelines allow for a broad scale assessment of water quality condition, but where applicable, locally relevant guidelines should be adopted. In Queensland, discharges to the marine environment are regulated by the Department of Environment and Resource Management (DERM), formerly the Environment Protection Agency (EPA). In the current instance,

given that there are only limited relevant EVs or WQOs established for Port Curtis, in accordance with EPP (Water) 1997, the Queensland Water Quality Guidelines (QWQG; DERM, 2009) shall be adopted for assessing potential impacts from the brine discharge to Port Curtis. The QWQG have been drafted to address the need for more locally specific water quality guidelines by:

- Providing guideline values (numbers) that are tailored to Queensland regions and water types
- Providing a process/framework for deriving and applying local guidelines for waters in Queensland (i.e. more specific guidelines than those in the QWQG).

The spatial limits of the marine waters of Queensland to which the QWQG apply are taken to be the three nautical-mile limit. The QWQG have been derived for specific areas throughout Queensland, where every effort has been made to ensure that there are seamless boundaries with any regional guidelines derived for adjacent Commonwealth waters.

The QWQG are technical guidelines, primarily for the protection of Queensland aquatic ecosystems. The guidelines include locally and regionally relevant water quality data for fresh, estuarine and marine waters. The DERM has been collecting water quality data from reference (unimpacted or minimally impacted) waterways since 1992. The EPA has used these data, together with data collected throughout Queensland by a range of government agencies, tertiary institutions and other organisations, to derive the QWQG. Any future water quality monitoring should rely on these guidelines, and the default trigger values which protect 95% of species, as defined by ANZECC/ARMCANZ (2000), where applicable.

The QWQG water quality objectives for the Central Coast Queensland Region (DERM, 2009) and the default trigger values for physical and chemical stressors for slightly disturbed ecosystems in marine waters of tropical Australia (ANZECC/ARMCANZ, 2000) are presented in Table 2.4.

Table 2.4 Water quality objectives for tropical marine waters near Gladstone.

	QWQG (DERM, 2009)	ANZECC/ARMCANZ (2000)
Ammonia N (µg/L)	8	1 – 10
Oxidised N (µg/L)	3	2 - 8
Organic N (µg/L)	180	
Total N (µg/L)	200	100
Filterable P (µg/L)	6	5
Total P (µg/L)	20	15
Chlorophyll-a (µg/L)	2.0	0.7 – 1.4
DO (% saturation). Upper	100	ND
DO (% saturation). Lower	90	90
Turbidity (NTU)	6	1 – 20
Secchi (m)	1.5	ND
Suspended solids (mg/L)	15	ND
pH. Upper	8.4	8.4
pH. Lower	8.0	8.0
Conductivity (µS/cm)	n/a	ND

2.4 Marine species of conservation significance

2.4.1 Dugong

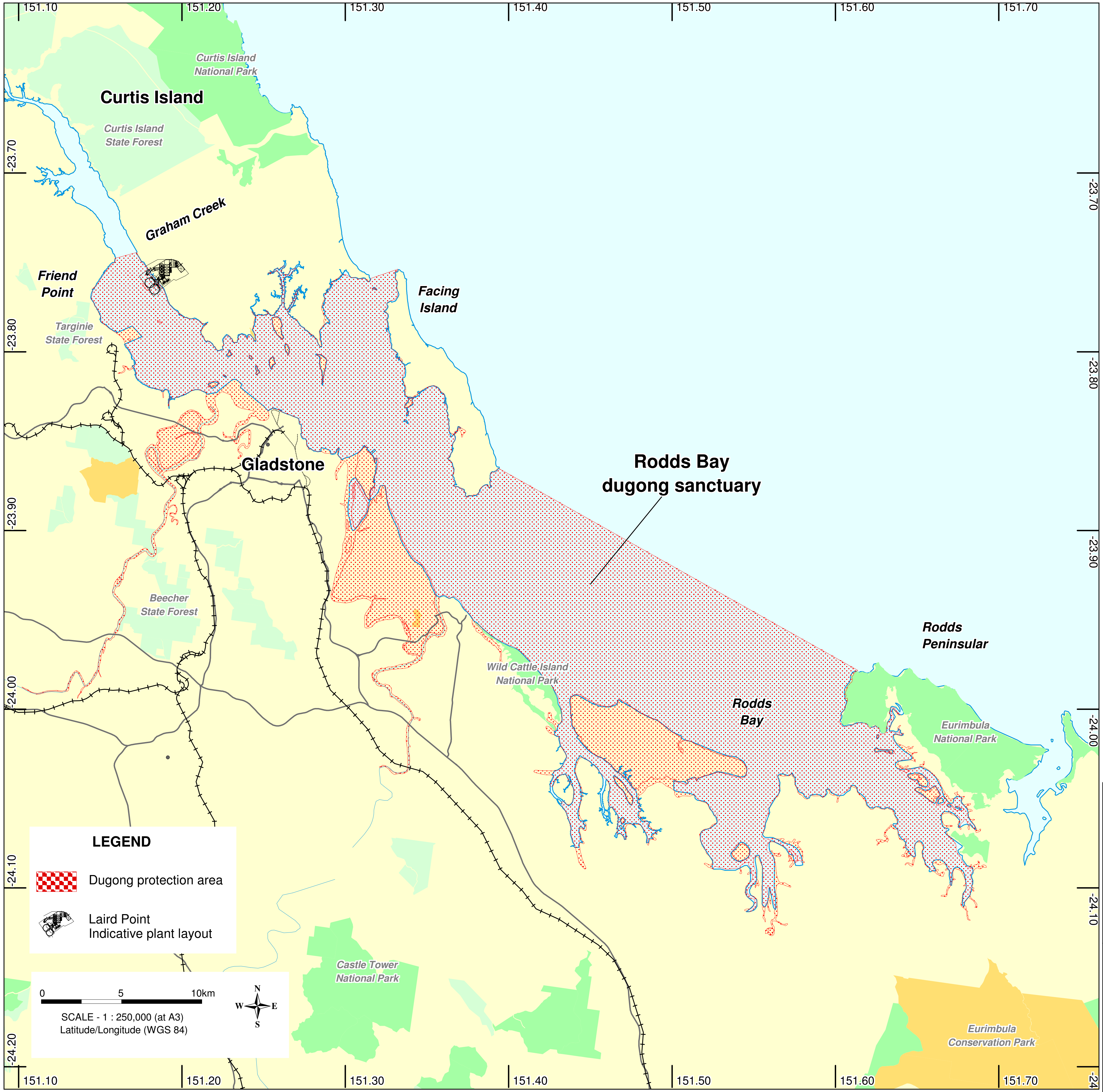
The dugong (*Dugong dugon*) is listed as vulnerable extinction under the Queensland *Nature Conservation Act 1992* (NC Act 1992) and is also listed as vulnerable by the International Union for the Conservation of Nature (IUCN). There is a significant and long-term decline in the population of dugong along the Queensland urban coast (Dobbs et al. 2008).

Sixteen Dugong Protection Areas are declared under the NC Act 1992, and as Special Management Areas under the *Great Barrier Reef Marine Park Regulations 1983* and the *Great Barrier Reef Marine Park Zoning Plan 2003*. The Great Barrier Reef Marine Park Authority's (GBRMPA) primary management intent for dugong conservation in the Great Barrier Reef Marine Park is to facilitate the recovery of dugong populations such that they fulfil their ecological role within the Great Barrier Reef ecosystem. To do this, GBRMPA (2007) identify two objectives:

- From Cooktown south, the mortality of dugongs from all human-related causes should be reduced to as close to zero as possible (for example less than 10 dugongs per year) to facilitate population recovery and where possible allow for future sustainable traditional use of marine resources.
- The quality and extent of habitat for dugongs should be protected, including feeding, calving and mating areas and migratory pathways.

The Rodds Bay/Port Curtis area (refer Figure 2.9) including the area adjacent to the proposed development site is designated a Dugong Protection Area "B". Dugong Protection Areas are a two tiered management scheme where Dugong Protection Area "A" represents the most significant dugong habitat in the southern Great Barrier Reef while Dugong Protection Area "B" represents habitat that is less significant but still important. The main difference in management arrangements between Dugong Protection Areas "A" and "B" relate to commercial mesh netting fishing regulations.

Dugong (*Dugong dugon*) are associated with seagrass beds in the Port Curtis region, however, the region is not identified as supporting large populations of these animals. The nearest large populations of dugong occur in Shoalwater Bay to the north and Hervey Bay to the south (Table 2.5). The dugong that do occur in the Port Curtis region are centred around the Rodds Bay area (Lawler and Marsh 2001), however they are recorded using seagrass beds in the northern part of Port Curtis such as those near Wiggins Island (Taylor et al. 2007; Chartrand et al. 2009). During field investigations as part of this study, dugongs were seen near Friend Point.



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0	14/09/2009	Issued for use	JB	MM		

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Figure 2.9 Map of the Rodds Bay Dugong Protection Area

Project No: 301001-00752	Figure: 00752-00-EN-DAL-0144	Rev: 1

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Table 2.5 Dugong population estimates in Dugong Protection Areas in central and southern Queensland (from Lawler and Marsh 2001)

Rodds Bay	Hervey Bay/Great Sandy Straits	Shoalwater Bay	Hinchinbrook Channel	Cleveland Bay	Repulse Bay	Upstart Bay
55 ± 37	1,673 ± 521	452 ± 132	725 ± 436	362 ± 157	90 ± 57	25 ± 26

2.4.2 Marine turtles

The conservation status of marine turtle species found in Australian waters is identified in Table 2.6. Currently, there is a Recovery Plan in place under the *Environment Protection and Biodiversity Conservation Act 1999* for all marine turtle species in Australia.

Table 2.6 The conservation status of marine turtles found in Australian waters.

Species name	Conservation Status		
	IUCN	EPBC Act	NC Act
Green turtle (Chelonia mydas)	Endangered	Vulnerable	Vulnerable
Hawksbill turtle (Eretmochelys imbricata)	Critically Endangered	Vulnerable	Vulnerable
Flatback turtle (Natator depressus)	Data deficient	Vulnerable	Vulnerable
Olive Ridley turtle (Lepidochelys olivacea)	Vulnerable	Endangered	Endangered
Leatherback turtle (Dermochelys coriacea)	Critically Endangered	Endangered	Endangered
Loggerhead turtle (Caretta caretta)	Endangered	Endangered	Endangered

Key: IUCN = The International Union for the Conservation of Nature, EPBC Act = Commonwealth *Environment Protection and Biodiversity Conservation Act 1999*, and NC Act = Queensland *Nature Conservation Act 1992*.

Marine turtles are long-lived and late maturing with maturity reached at between 30 and 50 years of age (Miller 1996). Marine turtles nest on mainland coastal beaches and offshore islands. They do not nest in estuarine areas such as those at and adjacent to the area of the proposed development location at Laird Point. Figure 2.10 through to Figure 2.12 describe the recorded nesting areas for the six marine turtle species in eastern and northern Australia.

Female marine turtles emerge from the water, generally at night, and move up the shoreline to select a nesting location. Most females do not nest in consecutive years (Miller 1996). However, a female marine turtle may lay several clutches of eggs per year (Limpus et al. 1984). Nesting marine turtles generally demonstrate fidelity to a nesting beach and return to nest on their natal beach with a very high degree of precision (Limpus et al. 1984). The process by which turtles select nesting sites along a beach has not been clarified (Miller 1996), however light regime is considered to have a significant impact on the emergence of female marine turtles from the ocean.

Marine turtles may also emerge from the water and return without attempting to excavate a nest or lay eggs – a phenomenon known as a “false crawl”. Nesting generally occurs between the high water mark and the foredune, however, nests may also be laid below the high tide mark (Whiting et al. 2007). If inundation of nests is significant the nest becomes unviable.

The sex ratio of turtle hatchlings is dependent on the temperature of incubation which is a function of sand colour. Nests in darker sand incubate at higher temperatures and produce more females (Hays et al. 2001).

Once hatched, lighting cues are identified as critical for hatchlings to move from the beach to the ocean – a behaviour known as sea-finding. In simple terms where there are no anthropogenic light sources, hatchlings move away from the dark silhouetted shoreline towards the brighter ocean horizon. Brightness in this context however, is a term that encompasses wavelength and intensity (Witherington and Martin 1996). Further, the heterogeneity of the light regime can also act as a cue. That is, hatchlings may orientate away from a horizon that has spatial patterns of light and shadow which in practical terms would see them orientate away from the shore and head towards the more homogenous light environment of the ocean horizon (Godfrey and Barreto 1995; Witherington and Martin, 1996). Changes to lighting regime can impact hatchlings if light sources are at the nesting beach, on the foreshore adjacent to the nesting beach, or offshore. Lights at a nesting beach can result in turtle hatchlings heading inland rather than into the ocean with subsequent mortality. Lights adjacent to nesting beaches can result in hatchlings entering the ocean safely, only to re-emerge closer to the light source.

It is known that the endemic flatback turtle (*Natator depressus*) nests on the eastern beaches of Curtis, Facing and Hummock Hill Islands (Limpus et al. 2002; 2006; Hodge et al. 2006). The South End area of Curtis Island is the key flatback nesting area in the region and it is identified nationally as a medium density rookery (Limpus et al. 2006). Nesting activity reaches a peak in late November – early December, and ceases by about late January. Hatchlings emerge from nests during early December until about late March, with a peak of hatchling activity in February (Limpus, 2007).

Green turtles (*Chelonia mydas*) and loggerhead turtles (*Caretta caretta*) may also nest sporadically in similar areas, however important rookeries for these two species lie elsewhere. In central Queensland, two key nesting areas are the Capricorn Bunker Group of islands for green turtles, and the Bundaberg coast for loggerhead turtles. Leatherback turtles (*Dermochelys coriacea*) and Hawksbill turtles (*Eretmochelys imbricata*) do not nest in the area (Limpus and McLachlan 1994).

Foraging habitats and preferred food items for the marine turtles species that typically feed in Port Curtis are identified in Table 2.7.

Table 2.7 Foraging habitats and preferred food items of the various marine turtle species.

Turtle Species	Foraging Habitats	Preferred Food Items	Reference
Green turtle (Chelonia mydas)	Shallow coastal area, in particular seagrass beds	Seagrass and seaweeds although juveniles are also carnivorous	Brand-Gardner et al. (1999)
Hawksbill turtle (Eretmochelys imbricata)	Rocky reef and coral reef habitats	Algae, seagrass and sponges	Limpus (2009a)
Flatback turtle (Natator depressus)	Shallow coastal environments including rocky reef and sedimentary habitats	A wide variety of soft bodied animals including soft corals, sea pens, sea cucumbers, jellyfish and other large plankton.	Limpus (2007)
Loggerhead turtle (Caretta caretta)	A wide range of intertidal and sub-tidal habitats including coral and rocky reefs, seagrass meadows, and unvegetated sand or mud areas.	Although diet is diverse, typical items include bivalve and gastropod molluscs and crabs.	Limpus (2008a)

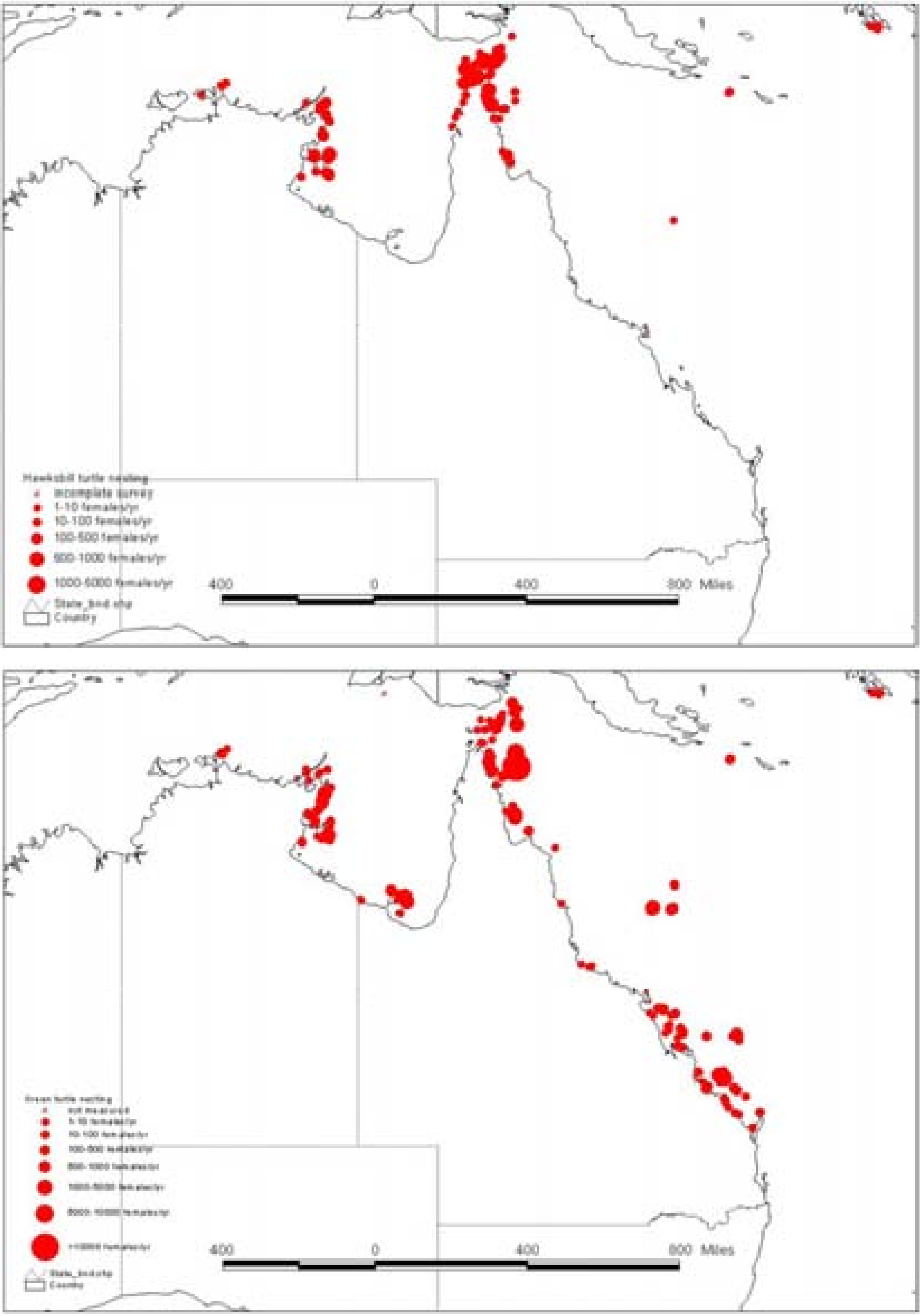


Figure 2.10 Nesting locations in northern and eastern Australia for hawksbill turtles (top) and green turtles (bottom) (from Limpus and Miller, 2008).

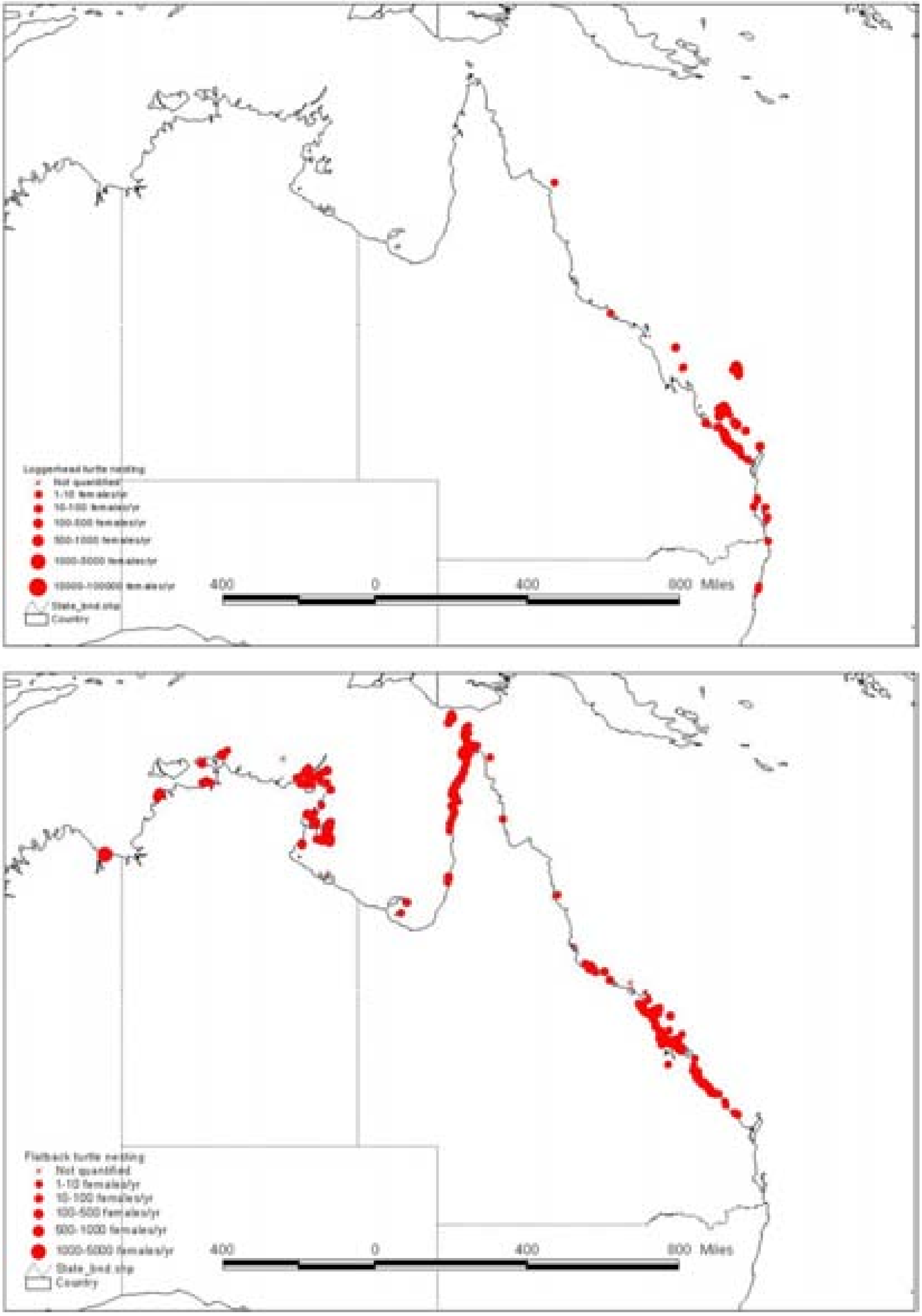


Figure 2.11 Nesting locations in northern and eastern Australia for loggerhead turtles (top) and flatback turtles (bottom) (from Limpus and Miller, 2008).

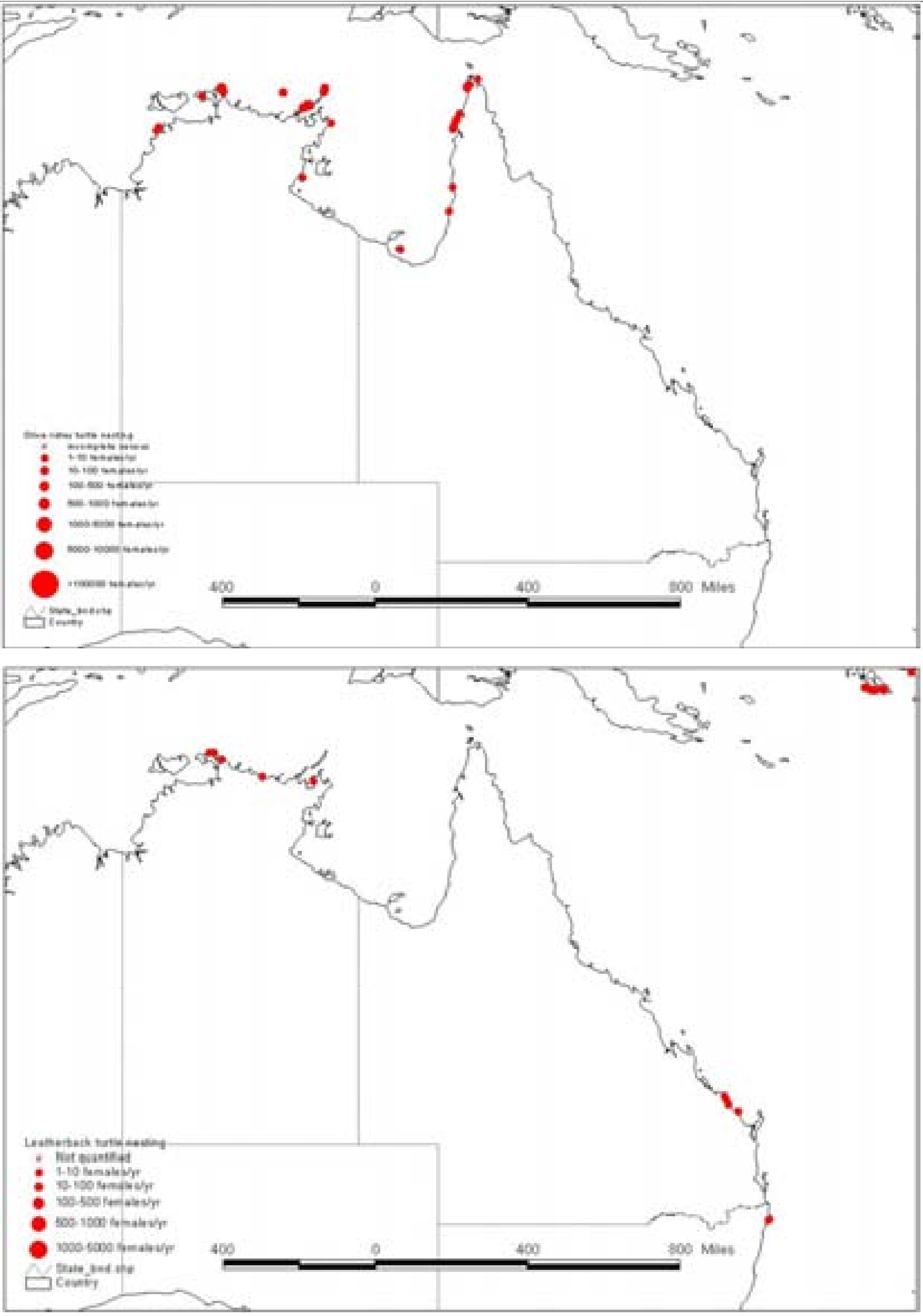


Figure 2.12 Nesting locations in northern and eastern Australia for olive Ridley turtles (top) and leatherback turtles (bottom) (from Limpus and Miller, 2008).

2.4.3 Cetacean - whales and dolphins

The EPBC Protected Matters Database search identified ten (10) cetacean species that may occur in the Port Curtis region including offshore areas. Of these, the Indo-Pacific humpback dolphin (*Sousa chinensis)*, the Australian snubfin dolphin (*Orcaella heinsohni*) and the bottlenose dolphin (*Tursiops aduncus* and *Tursiops truncatus*) – are known to occur adjacent to the proposed development locations. Coastal dolphins are recognised among the most threatened species of cetaceans due to their close proximity to a range of direct and indirect human impacts (Thompson et al., 2000)

Both the Australian snubfin dolphin and the Indo-Pacific humpback dolphins usually inhabit shallow coastal waters of less than 20 m depth and are often associated with rivers and estuarine systems, enclosed bays and coastal lagoons (Corkeron et al. 1997, Hale et al. 1998; Parra 2006). There are no estimates of dolphin abundance in Port Curtis. The Australian snubfin dolphin is endemic to Australia but may also occur in Papua New Guinea (Beasley et al. 2005). Previously the Australian snubfin dolphin was identified incorrectly as the widely distributed Irrawaddy dolphin (*Orcaella brevirostris*). Recent genetic studies on Indo-Pacific humpback dolphins indicate Australian populations may also represent a different species only found in Australia (Frère et al., 2008).

Parra (2006) examined habitat use of both Australian snubfin dolphins and Indo-Pacific humpback dolphins in Cleveland Bay (Townsville). While there was significant overlap in habitat use by the two species, differences were also found. Australian snubfin dolphins preferred slightly shallower (1–2 m) waters than humpback dolphins (2–5 m). Shallow areas with seagrass ranked high in the habitat preferences of snubfin dolphins, whereas humpback dolphins favoured dredged channels.

The diet of both Australian snubfin dolphins and Indo-Pacific humpback dolphins has been examined by Parra and Jedensjö (2009). The Australian snubfin dolphin consumes fish, cephalopods (squid and cuttlefish), bivalves and decapod crustaceans (prawns). The fish families consumed most frequently by the Australian snubfin dolphin were the Sciaenidae, Leiognathidae, Sillaginidae, Haemulidae, Apogonidae and Synodontidae. The Indo-Pacific humpback dolphin consumed cephalopods, bivalves and decapod crustaceans less frequently than Australian snubfin dolphins. The fish families consumed most frequently by the Australian snubfin dolphin were Apogonidae, Mugilidae, Clupeidae, Sciaenidae and Haemulidae.

Due to the inshore nature of the site it is considered that the following cetacean species identified in the EPBC Protected Matters Database search do not occur at or adjacent to the proposed development location as they are principally oceanic species: minke whale (*Balaenoptera acutorostrata*)*,* humpback whale (*Megaptera novaeangliae*)*,* Bryde's whale (*Balaenoptera edeni*), Risso's dolphin (*Grampus griseus*), spotted dolphin (*Stenella attenuata*), common dolphin (*Delphinus delphis*) and the killer whale (*Orcinus orca*).

2.4.4 Estuarine crocodile

The southern most range of the estuarine crocodile (*Crocodylus porosus*) is generally recognised as the Fitzroy River although individuals straggle as far south as Colosseum Inlet and Seven Mile Creek systems. While it is plausible that estuarine crocodile may be sited near the proposed LNG Facility, the area does not represent key habitat for the species. The key areas for estuarine crocodile populations in Queensland is the north western Cape York Peninsula, particularly parts of the Wenlock River and the Lakefield National Park (Read et al., 2004).

2.4.5 Sea snakes

An EPBC Protected Matters Database search identified that there were 12 species of sea snakes that may occur in the region of the proposed development. The species are as follows:

- Horned seasnake (Acalyptophis peronii)
- Dubois' seasnake (Aipysurus duboisii)
- Spine-tailed seasnake (Aipysurus eydouxii)
- Small headed seasnake (Hydrophis mcdowelli)
- Olive seasnake (Aipysurus laevis)
- Stokes seasnake (Astrotia stokesii)
- Spectacled seasnake (Disteria kingii)
- Olive-headed seasnake (Disteria major)
- Turtle-headed seasnake (Emydocephalus annulatus)
- Elegant seasnake (Hydrophis elegans)
- Spine-bellied seasnake (Lapemis hardwickii), and
- Yellow-bellied seasnake (Pelamis platurus).

There are clear and significant knowledge gaps with respect to the distribution and abundance of sea snakes in Australia. However, the following sea snake species are considered to prefer inshore waters with sandy/muddy substrata and moderate turbidity: elegant seasnake, spine-bellied seasnake, and the small headed seasnake (Heatwole and Cogger 1993). As such, these are the sea snake species most likely to occur in the vicinity of Laird Point. Coral reef, inter-reefal habitats, or the open ocean are likely to be preferred habitats for the remaining species (Heatwole and Cogger 1993; Marcos and Lanyon 2004; Lukoschek et al. 2007).

2.4.6 Pipefish and seahorses

Pipefishes and seahorses are listed marine species under the EPBC Act (section 248). An EPBC Protected Matters Database search identified that there were 33 species of syngnathids (pipefish and pipehorses) that may occur in the region of the proposed development:

- Hairy pygmy pipehorse (Acentronura tentaculata)
- Tryon's pipefish (Campichthys tryoni)
- Pacific short-bodied pipefish (Choeroichthys brachysoma)
- Brown-banded pipefish (Corythoichthys amplexus)
- Yellow-banded pipefish (Corythoichthys flavofasciatus)
- Reef-top pipefish (Corythoichthys haematopterus)
- Banded pipefish (Corythoichthys intestinalis)
- Ocellated pipefish (Corythoichthys ocellatus)
- Paxton's pipefish (Corythoichthys paxtoni)

- Schultz's pipefish (Corythoichthys schultzi)
- Blue-stripe pipefish (Doryhamphus excisus)
- Girdled pipefish (Fetucalex cincatus)
- Tiger pipefish (Filicampus tigris)
- Duncker's pipefish (Halicampus dunckeri)
- Mud pipefish (Halicampus grayi)
- Glittering pipefish (Halicampus nitidis)
- Spiny-snout pipefish (Halicampus spinirostris)
- Blue-spotted pipefish (Hippichthys cyanospilos)
- Madura pipefish (Hippichthys heptagonus)
- Beady pipefish (Hippichthys penicillus)
- Pygmy seahorse (Hippocampus bargibanti)
- Spotted seahorse (Hippocampus kuda)
- Flat-face seahorse (Hippocampus planifrons)
- Zebra seahorse (Hippocampus zebra)
- Javelin seahorse (Lissocampus runa)
- Shortnose pipefish (Micrognathus andersoni)
- Thorn-tailed pipefish (Micrognathus brevirostris)
- Painted pipefish (Nannocampus pictus)
- Pipehorse (Solegnathus hardwickii)
- Robust ghost pipefish (Solegnathus cyanopterus)
- Ornate ghost pipefish (Solegnathus paradoxus)
- Double-ended pipefish (Syngnathoides biaculeatus)
- Short-tailed pipefish (Trachyrhamphus bicoarctatus).

Currie and Connolly (2004) identified the presence of an unidentified species of seahorse and an unidentified species of pipefish. Although information gaps exist, it is known that many species of pipefish prefer shallow inshore habitat including both bare sand/mud and seagrass habitat which are prevalent adjacent to the proposed development sites.

2.5 Soft sediment macrobenthic infaunal assemblages

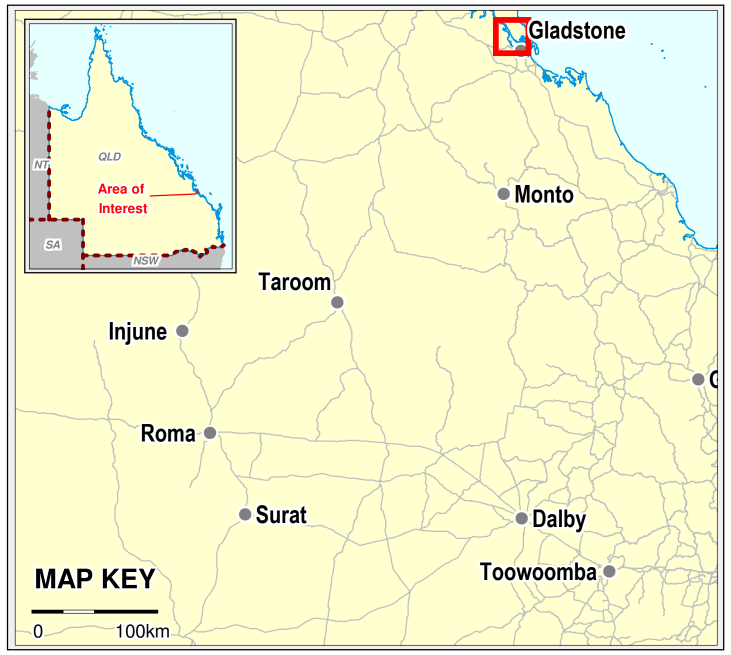
Through a variety of processes (e.g. bioturbation, feeding and excretion), macrobenthic infauna regulate physical and chemical conditions at the sediment-water interface, promote the decomposition of organic matter, and recycling of nutrients required by plants for photosynthesis. Macrobenthic infauna also form important prey items for many large invertebrates and fish species (including species of direct fisheries significance), and are therefore an important linkage in the transfer of energy through the coastal food web.

Currie and Small (2005; 2006) undertook a comprehensive assessment of the macrobenthic infaunal assemblage of Port Curtis over a six year period, and Alquezar (2008) also undertook additional work, in part, in the area of interest for the proposed project. Overall, the assemblage sampled by Currie and Small (2005; 2006) throughout the Port Curtis region is dominated by filter feeders which accounted for more than 50% of the total abundance and nearly 30% of the total species richness. The bivalve mollusc *Carditella torresi* was the most abundant species which accounted for more than 14% of the total abundance. The ascidian *Ascidia sydneiensis* was the second most abundant species accounting for less than 4% of the total abundance. A further eight species including five bivalves (*Corbula tunicata*, *Mimachlamys gloriosa*, *Leionuculana superba*, *Mactra abbreviata* and *Placamen tiara*), one ascidian (*Ascidiacea* sp.), one polychaete worm (*Eunice vittata*) and one caridean shrimp (*Alpheus* sp.) each contributed between 2-3% of the total abundance. The majority of organisms (98% of the species) were collected infrequently and individually contributed less than 2% of the total abundance. The species richness of the macrobenthic infaunal assemblage was generally lower than in higher latitude embayments elsewhere in Australia (for example, Moreton Bay).

In terms of spatial variability of the macrobenthic infaunal assemblage, species richness and abundance were found to be lowest on fine muddy substrates in intertidal areas, and greatest in coarse sandy sediments that predominated in the deeper channels of the estuary. The pattern of freshwater flow was identified as the principal source of temporal variation in the assemblage with regional rainfall and freshwater inflow positively correlated with macrobenthic infaunal abundance.

Some information presented by Currie and Small (2006) can be disaggregated into a smaller spatial scale of relevance to the proposed development location. Sampling stations closest to Laird Point had macrobenthic infaunal assemblage that was low density and numerically dominated by the deposit feeding bivalve *Leionuculana superba* and the predatory polychaetes *Eunice* species 1, *Nephtys* species 1 and *Leanira* sp 1.

Alquezar (2008) provides an overview of the structure of the macrobenthic infaunal assemblage in Port Curtis including in the vicinity of Laird Point. Alquezar (2008) sampled 24 sites within Port Curtis, nine of which are in the vicinity of the proposed LNG plant (sites one to nine) (Figure 2.13). From Alquezar (2008), the results for the total average abundance, taxa richness, taxa diversity (Shannon-Weiner Index) and evenness per replicate per site are summarised in Table 2.8.



LEGEND

Survey Sites extracted from Macroinvertebrate and Sediment Assessment for the Curtis Island Gas Pipeline EIS, Alquezar (2008).

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Satellite imagery (GeoEye-1 on 24 March 2009)

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Map Grid of Australia Zone 56
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Macroinvertebrate Survey Sites in Port Curtis used by Alquezar (2008)

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Table 2.8 Univariate attributes of the macrobenthic infaunal assemblage at 24 sites in Port Curtis (modified from Alquezar, 2008). Locations 1 to 9 are within or adjacent to the Development Footprint for the Current Project.

Site No.	Total Average Abundance per replicate	Taxa Richness per replicate	Taxa Diversity	Evenness
1*	6.6	4.6	1.1	0.9
2*	3.3	2.7	0.9	0.8
3*	7.0	6.0	1.7	0.8
4*	12.0	6.7	1.5	0.6
5*	6.3	4.6	1.5	0.8
6*	1.6	1.7	0.5	1.0
7*	6.3	5.3	1.2	0.9
8*	6.3	5.6	1.7	0.9
9*	37.0	16.0	2.4	0.3
10	11.0	9.0	2.1	0.7
11	14.0	9.0	1.9	0.6
12	18.0	11.0	2.1	0.6
13	18.0	5.6	0.9	0.3
14	2.3	2.3	0.7	1.0
15	7.0	5.0	1.4	0.7
16	6.6	4.0	1.2	0.6
17	2.3	2.0	0.6	0.9
18	4.3	3.6	3.6	0.8
19	18.0	9.3	9.3	0.5
20	4.6	3.3	3.3	0.8
21	1.0	1.0	1.0	0.6
22	2.3	1.0	1.0	0.1
23	17.0	11.0	11.0	0.5
24	2.6	2.3	2.3	0.9

2.6 Plankton

Plankton consists of phytoplankton (floating plants) and zooplankton (floating animals).

Phytoplankton is an important source of primary production in coastal waters and is recognised as an important indicator of environmental health. In particular, phytoplankton is a good indicator of nutrient enrichment from anthropogenic sources. Phytoplankton concentrations are measured by assessing the concentration of chlorophyll *a* in the water column. Chlorophyll *a* is the principal photosynthetic pigment possessed by phytoplankton. Prediction of chlorophyll *a* winter levels in the Port of Gladstone range from 0.6 to 3.2 µg/L and are between 2.0 µg/L and 2.3 µg/L in waters adjacent to Curtis Island. These values are below the relevant ANZECC/ARMCANZ guideline (2000) trigger value of 4.0 µg/L (Currie and Small 2006).

Zooplankton is further divisible into holoplankton (animals that spend their whole life cycle as plankton) and meroplankton (animals that spend only part of their life cycle as plankton). Meroplankton includes larvae of sessile benthic organisms (e.g. oysters) as well as fish and prawn larvae including those of commercial and recreational significance. Zooplankton includes animals that graze on phytoplankton as well as carnivores that consume other zooplankton. Both phytoplankton and zooplankton are key components of the food web of coastal waters.

With the exception of Moreton Bay, inshore plankton assemblages in Queensland are not well studied and the research in Moreton Bay is not directly transferable to the Port Curtis region. Although most plankton is microscopic, the most visible component of the planktonic assemblage are the large scyphozoan jellyfishes such as *Catostylus mosaicus* which occur in Port Curtis.

2.7 Exotic marine species and marine pests

The Port of Gladstone currently receives vessels from various Australian ports as well as from overseas ports from a number of countries including Japan, China, Korea, Singapore and the west coast of the U.S.A. Therefore there is the potential for introduction of exotic marine species through ballast water, hull fouling and fouling of internal sea water pipes. A *National System for the Prevention and Management of Marine Pest Incursions* is utilised to address all aspects of the prevention, management and control of marine pest incursions. The system considers measures to reduce the risk to primary invasion through ballast water and fouling, as well measures to control the spread of existing introduced marine pests as a result of translocation. The Port of Gladstone is one of 18 ports in Australia that is targeted for ongoing monitoring for marine pests as it is recognised that there is an ongoing high risk of introductions and translocations to the area. However, the monitoring program is yet to commence in Port Curtis.

Previously, Lewis et al. (2001) undertook a study of the distribution and abundance and risk of exotic marine species in Port Curtis and identified the presence of nine exotic marine species but none of these are classified as marine pest species. Marine pest species are those introduced species that can have a significant impact on marine industries, the marine environment, coastal communities and the economy. The nine exotic marine species present in Port Curtis consists of four bryozoans (*Amathia distans*, *Bugula neritina*, *Cryptosula pallasiana*, and *Watersporia subtoraquata*), two ascidians (*Botrylloides leachi* and *Styela plicata*), one isopod crustacean (*Paracerceis sculpta*), one hydrozoan (*Obelia longissima*) and one dinoflagellate (*Alexandrium* sp.). These species have successfully colonised ports within Australia and worldwide and are unlikely to have significant impact on native assemblages.

2.8 Fish and nektobenthic invertebrates

All sub-tropical inshore fish assemblages are temporally and spatially variable at many different scales. Components of this fish assemblage in the Port Curtis region support regionally important commercial and recreational fisheries. Although information gaps exist, Currie and Connolly (2006)

provide data on the structure of the inshore fish assemblage in the Port Curtis region. The study of Currie and Connolly utilised small trawl gear over sedimentary habitats. As such, it is limited in its use for describing the presence and abundance of larger species, and those that associate with rock or reef habitat.

The fish assemblage of shallow, nearshore sedimentary parts of Port Curtis area was found to be diverse with 88 species present but dominated by two small schooling species which is typical of the fauna recorded in inshore areas elsewhere in Queensland (e.g. Hyland 1988; Blaber et al. 1989; Reid and Campbell 1998; Thomas and Connolly 2001; McPhee and Skilleter 2005). In the case of Port Curtis, the numerically dominant species were ponyfish (*Leiognathus equulus*) and herring (*Herklotsichthys castelnaui*) which in combination comprised approximately 50% of the total abundance

The structure of the sub-tidal fish assemblage in the vicinity of Laird Point was found to be similar to most other inshore sites surveyed in Port Curtis. The major components of this inshore grouping of sites surveyed were: common ponyfish (*Leiognathus equulus*), finny scad (*Megalapsis cordyla*), herring (*Herklotsichthys castelnaui*), yellow perchlet (*Ambassis marianus*), happy moments (*Siganus rivulatus*), large-scaled grinner (*Saurida undosquamis*), striped cardinalfish (*Apogon fasciatus*), yellow-fin tripod fish (*Tripodichthys angustifrons*), large-toothed flounder (*Pseudorhombus arsius*) and diver whiting (*Sillago maculata*). All of these species are common and widely distributed and typical of inshore habitats in sub-tropical Australia.

Saltmarsh and saltpan habitats tend to have lower species richness than other inshore habitats such as mangroves and seagrass (Sheaves et al. 2007), but nonetheless provide important habitat for fish species, including those of recreational and commercial significance. Although fish utilisation of saltmarsh in the Gladstone region is not well studied, Sheaves et al. (2007) presents information on the saltmarsh fish assemblage for Munduran Creek which drains into The Narrows approximately 15 km from the proposed development location. The species recorded and their abundances are listed in Table 2.9. A similar suite of species are likely to occur in the area reclaimed for the proposed LNG Facility.

Thomas and Connolly (2001) have also undertaken relevant work looking at the use of fish utilisation of saltmarsh habitat elsewhere in Queensland. Fish can extend many hundreds of metres into salt marsh habitats on spring tides. For example at Meldale in Pumicestone Passage and Theodolite Creek in Hervey Bay, fish were recorded 413 m and 201 m respectively from sub-tidal water. The relative importance of salt marsh in terms of use by fisheries resources is generally considered to decrease with decreasing depth. This parameter is often related to distance from mangroves (if present) or the water’s edge, however local habitat heterogeneity may confound such a relationship. For two salt marshes (Meldale and Theodolite Creek), Thomas and Connolly (2001) identified consistent fish density across the first 200 m of the salt marsh (from the water’s edge), with reduced densities farther on to the salt marsh.

Table 2.9 The abundance of fish species in salt pan areas in Munduran Creek (modified from Sheaves et al., 2007)

Species	Abundance (number caught)
Liza subviridis (greenback mullet)	273
Gerres filamentosus (whipfin silverbiddy)	125
Mugil cephalus (sea mullet)	30
Leiognathus equulus (common ponyfish)	23
Valamugil sehali (bluespot mullet)	21
Herklotsichthys castelnaui (Castelnaui's herring)	16
Leiognathus decorus (decorated ponyfish)	14
Acanthopagrus australis (yellowfin bream)	10
Ambassis spp. (perchlet)	10
Nematalosa come (bony bream)	10
Valamugil sp. A. (mullet)	9
Selenatoca multifasciata (southern butterfish)	8
Sillago sihama (northern whiting)	5
Thryssa hamiltoni (Hamilton's anchovy)	3
Lutjanus argentimaculatus (mangrove jack)	3
Gerres erythrourus (deep-bodied silverbiddy)	3
Chanos chanos (milkfish)	2
Lates calcarifer (barramundi)	2
Gobid sp. A (goby)	1
Monodactylus argenteus (butter bream)	1
Scatophagus argus (spotted scat)	1
Siganus lineatus (striped rabbitfish)	1
Zenarcopterus buffonis (Buffon's river-garfish)	1
Terapon jarbua (Jarbua terapon)	1

Fish utilisation of the mangroves in the Port Curtis area has not been well studied, however Halliday and Young (1996) thoroughly examined density, biomass and species composition of mangrove forests further south at Tin Can Bay. Similar to the mangroves in Port Curtis, the mangroves examined by Halliday and Young (1996) were dominated by *Rhizophora stylosa*. They recorded 42 species from the mangrove forests and economically important species represented approximately 76% by number and 74% by weight of the total catch. The numerically dominant fish species were (in order): *Sillago analis* (yellowfin whiting), *Tetractenos hamiltoni* (common toadfish), *Gerres oyeana* (common

silverbiddy) and *Mugil georgii* (flat-tail mullet). The mean density of fish in the mangrove forest was 0.04 ± 0.01 m^{-2}, with a biomass of 1.3 ± 0.2 g/m^{-2}.

Although specific information is lacking, the rock and reef habitat within Port Curtis is likely to be utilised by a range of adult and juvenile fish species including yellowfin bream (*Acanthopagrus australis*), sweetlip (principally *Lethrinus fletus*), estuary cod (*Epinephelus coides*), and blubber-lip bream (*Plectorhincus* spp.).

In terms of fish species of conservation significance, the whale shark occurs in oceanic waters east of Facing and Curtis islands, and as such is unlikely to occur in an estuarine environment such as Port Curtis. The green sawfish (*Pristis zijsron*) are recorded in shallow inshore coastal environments including estuaries. However detailed records of the occurrence of the species from 1912 to 2004 identify that no individuals of the species have been recorded in the Gladstone region during that period (Stevens et al. 2005).The estuary stingray (*Dasyatis fluviorum*) is ranked as a high priority species by the DERM "Back on Track species prioritisation framework" which prioritises Queensland's native species to guide conservation, management and species recovery. The estuary stingray utilises a range of shallow inshore habitats and is likely to occur frequently within the area of the proposed development.

Nektobenthic invertebrates refers to large more mobile benthic invertebrates such as crabs, prawns and lobsters that are typically absent or significantly underestimated in standard benthic sampling gear such as grabs or sleds. Nektobenthic invertebrates are frequently important for fisheries. Although a comprehensive analysis is lacking, the Port Curtis area provides habitat for various portunid crabs including the blue swimmer crab (*Portunus pelagicus*), juvenile penaeid prawns (including tiger prawns (*Penaeus semisulcatus* and *Penaeus esculentus*), eastern king prawns (*Penaeus plebejus*) and banana prawns (*Penaeus merguiensis*), and mud crabs (*Scylla serrata*) (Walker 1997).

2.9 Fisheries resources

2.9.1 Commercial fisheries

Net and mud crab fisheries are the principal commercial fisheries that operate in the Port Curtis area, although beam trawling also occurs (Walker 1997). Net and crab fishers that operate in Port Curtis are also permitted to operate anywhere on the east coast in areas where these fishing activities are permissible. Commercial fishers that are endorsed to beam trawl in the Port Curtis area are only permitted to operate in Port Curtis and The Narrows, the mouth of the Fitzroy River and Keppel Bay.

Commercial fisheries in Queensland are monitored through a compulsory logbook program administered by the Queensland Primary Industries and Fisheries (QPI&F). Data collated from the logbook program is available via the Coastal Habitat and Resource Inventory System (CHRISweb) database[1] which is also administered by the QPI&F. A key consideration when interpreting information from the database is the spatial resolution which is very coarse. Commercial net and crab fishers record spatial information on catch and effort in 30 minute grid squares. In the current area of interest this scale includes all of the Gladstone Port Area and the Narrows area as well as significant area in offshore waters east of Curtis Island (Grid S30 in Figure 2.14). Further, catches within a reporting grid are only publicly available where five boats or more have accessed that particular grid in a given year.

[1] http://chrisweb.dpi.qld.gov.au/chris/

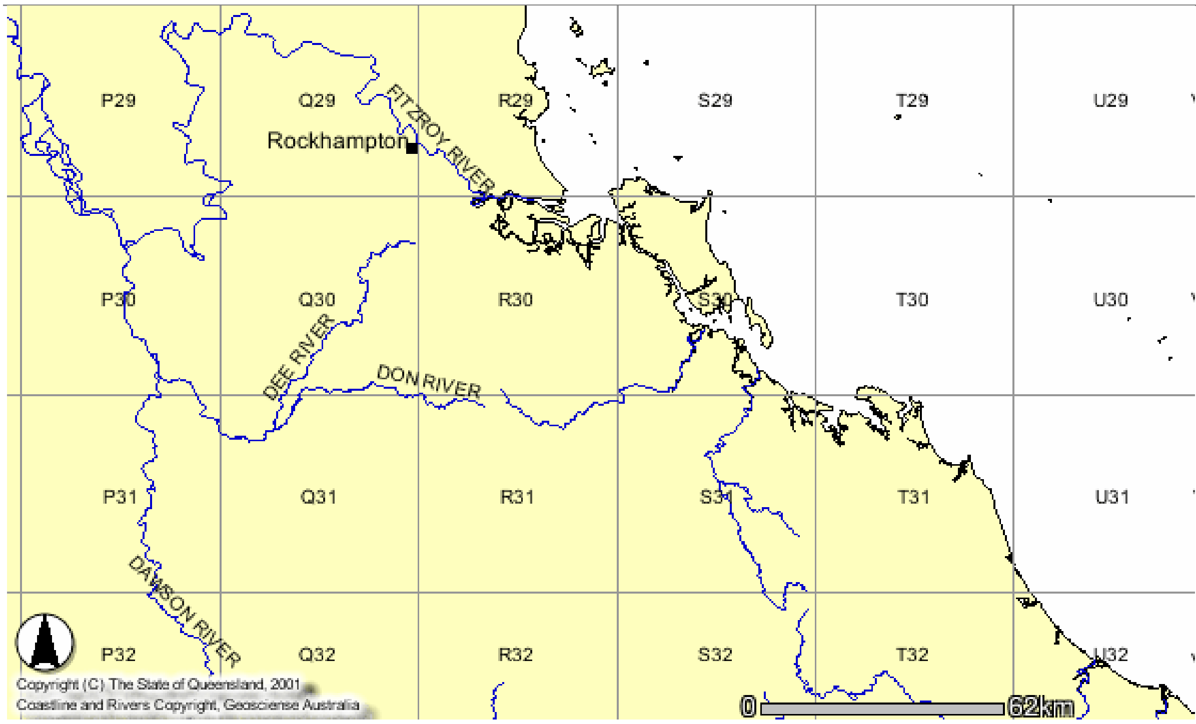

Figure 2.14 Map of the 30 minute grids for recording commercial fishing catch and effort in the Port Curtis region.

The annual volume and value of the catch for the commercial net and crab fishery in the Gladstone Port area (grid S30) between 1988 and 2005 is shown in Figure 2.15. Both the volume and value of the catch in the net and crab fishery has tended to increase over time with a more rapid increase since 2003, particularly for the net fishery. No data are currently publicly available for years after 2005. The crab fishery in the region is almost solely focussed on the mud crab (*Scylla serrata*). Most of the commercial mud crab fishery is concentrated in the Narrows and the creeks that drain into it (e.g. Graham Creek, D.McPhee pers. obs). By volume and value key target species in the net fishery include various species of shark (principally *Carcharinus* spp), blue threadfin salmon (*Eleutheronema tetradactylum*), mullet (*Mugil* spp.), barramundi (*Lates calcarifer*) and grey mackerel (*Scoberomorus semifasciatus*). A large range of other species are also captured and retained in the net fishery.

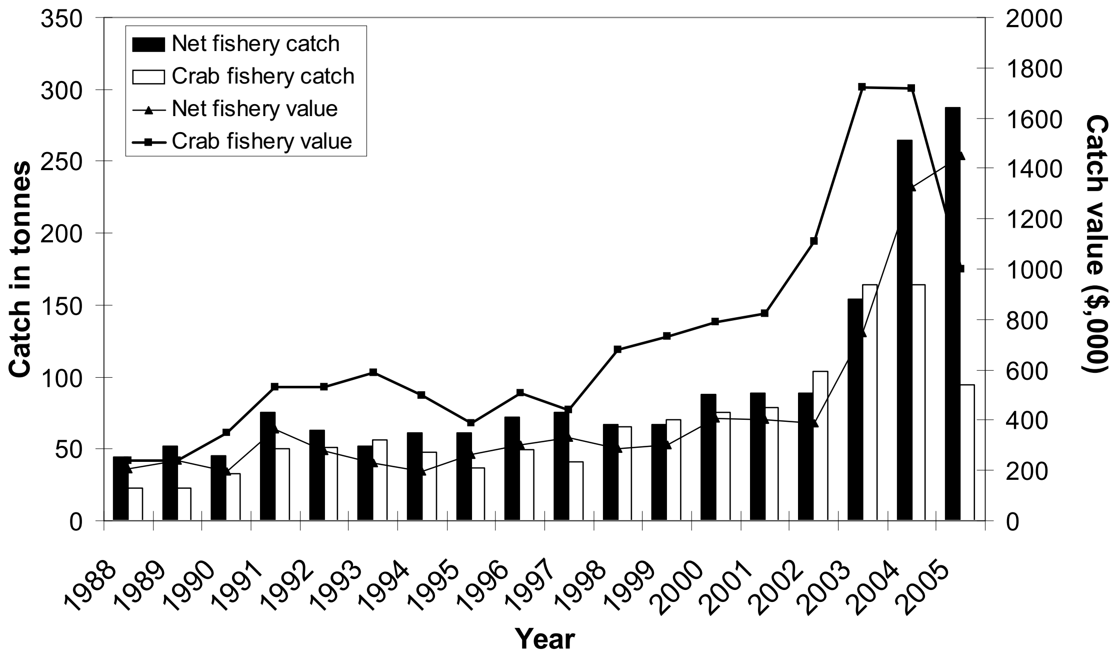

Figure 2.15 The annual volume and value of the commercial net and crab fishing catch between 1988 and 2005 in grid S30 which includes the Gladstone Port area.

The beam trawl fishery targets various species of prawns with banana prawns (*Penaeus merguiensis*), school prawns (*Metapenaeus macleayi*) and greasyback prawns (*Metapenaeus bennettae*) that dominant the catch. The beam trawl fishery within the Port Curtis/Fitzroy River/Keppel Bay area contributes approximately 15% of the Queensland beam trawl catch. However, while the Port Curtis region is within the area that can be accessed by the fishery, it is rarely done so in practice.

The beam trawl fishery is consistently dominated by catches taken from the mouth of the Fitzroy River (reporting grid R29) and Keppel Bay (reporting grid R30). Beam trawl catch in reporting grid S30 has only been reported five times in 17 years and volumes during these five years is low (Table 2.10). In the years where no catch is recorded, it is possible that beam trawl vessels did access the fishery, but the number of vessels that did so was less than five. Nonetheless it is clear from the available data that reporting grid S30 which contains the location of the proposed development is not an important area for the beam trawl fishery.

Table 2.10 Annual volume of prawn catch (tonnes) in the reporting grids that cover the Port Curtis/Fitzroy Beam Trawl Fishery.

Year	Grid R29	Grid R30	Grid S30	Grid T30	Grid T31
1988	22.1	15.0	-	4.5	1.8
1989	6.4	16.0	1.7	-	-
1990	5.8	19.3	-	-	-
1991	8.9	12.5	-	-	-
1992	7.0	20.2	-	4.7	3.6
1993	5.1	19.1	-	-	5.2
1994	5.2	26.7	-	-	7.5

1995	-	28.1	-	5.6	6.9
1996	5.2	27.1	1.7	-	5.2
1997	7.4	47.9	-	-	-
1998	5.3	42.4	-	-	-
1999	8.5	33.7	-	-	1.7
2000	10.7	28.7	-	-	-
2001	18.1	39.3	-	-	-
2002	10.5	29.9	-	-	-
2003	32.6	52.5	4.4	-	-
2004	29.5	30.1	-	-	-
2005	21.9	31.9	7.0	-	-

2.9.2 Recreational fisheries

Statewide recreational fishing surveys have been undertaken in 1997, 1999, 2002 and 2005. These surveys report catch and effort information at a broad spatial scale – the statistical division that a fisher resides in. Like information on commercial fishing, information on recreational fishing can be accessed through CHRISweb. In the current instance, the relevant statistical division is the Fitzroy Region and this is a large region comprising 13 local government areas with a total area of 122,972 km^2 and includes Rockhampton, Gladstone, Emerald, and Biloela.

The rank of importance in terms of harvest of the various inshore and estuarine finfish species for anglers residing in the Fitzroy statistical division in 2005 from the CHRISweb database is displayed in Table 2.11. This information demonstrates that whiting, mullet and bream are the three dominant finfish species harvested. As well as the targeting of finfish, extensive mud crabbing by recreational anglers occurs in The Narrows and the creek systems that drain into it. Platten et al. (2007) provide information on the levels of boat based fishing effort through central Queensland including Gladstone. From 1985 to 2005, boat registrations in the Gladstone region increased 110% from 2171 to 4581 with the vast majority of these boats used for recreational fishing. It was estimated that between the period June 2005 and May 2007, approximately 16395 boating trips commenced from the Gladstone Boat ramp (adjacent to Gladstone Volunteer Marine Rescue (VMR)) which is the main public boat ramp in the region. While the number of vessels that utilise the Laird Point and Graham Creek area is unknown, the Graham Creek area is recognised as a very important anchorage area for recreational vessels and an important area for recreational fishing, particularly mud crabbing.

Platten (2006) provides additional information on fishing club catches at a finer spatial scale, including the composition of the catch which is displayed in Figure 2.16. Platten (2006) clearly shows that whiting are the numerically dominant finfish captured by the Wanderer's Fishing Club which operates in various inshore and coastal areas of Port Curtis. The catches of fishing clubs are not necessarily indicative of the broader recreational fishing public (McPhee 2008).

Table 2.11 The rank of numerical importance of recreationally harvested taxa in the Fitzroy Statistical Division in 2005

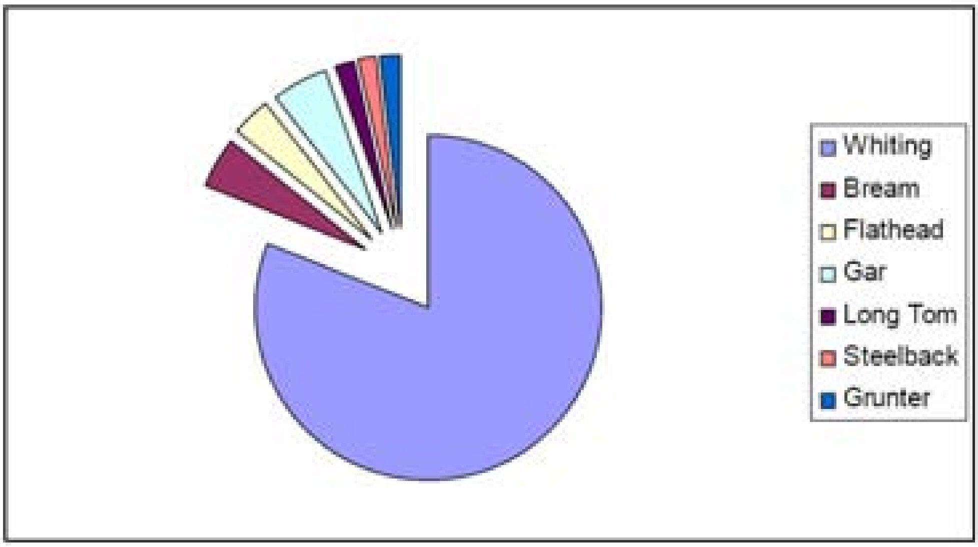

Figure 2.16 The finfish catch composition of catches by the Wanderers Fishing Club in the Port Curtis region between 1997 and 2000 (from Platten, 2006)

Rank	Taxa	Rank	Taxa
1	Whiting	11	Spotted mackerel
2	Mullet	12	Fingermark
3	Bream	13	Mangrove jack
4	Dart	14	Barramundi
5	School mackerel	15	Moses perch
6	Garfish	16	Shark
7	Grunter	17	Grey mackerel
8	Threadfin salmon (blue & king)	18	Queenfish
9	Flathead	19	Rays
10	Tailor	20	-

3. Impact assessment

Impact assessment involves assessing the potential impacts of the impacting processes on the existing environment should the development proceed through a risk based approach. The use of such an approach is widely adopted in environmental impact assessment and anthropogenic impacts on the environment in general (Fletcher 2005; Thomas and Elliott 2005; Astles et al. 2006). The assessment focuses on the construction and operation of the LNG Facility, including the construction of the MOF, and transport of employees and equipment to and from the mainland (Auckland Point) to the LNG Facility site.

The approach to the assessment of impacts involved identification of the key impact mechanisms and possible impacts associated with each mechanism, followed by a formal risk assessment. The Australia Pacific LNG risk methodology described in Volume 1 Chapter 4 of the EIS was used for the marine environment assessment with a modified set of consequence descriptors that are more applicable to the natural environment (Table 3.1).

Table 3.1 Risk assessment consequence categories used to assess impacts to the marine environment from the proposed project.

Classification	Consequence
Catastrophic (6)	Fundamental change to ecological structure and function through deterioration in water quality, geomorphic changes or habitat destruction/fragmentation, resulting in a reduction of over 40% in the regional occurrence of any habitat or resulting in a species no longer occurring in the relevant region as a result of direct or indirect impacts from the Project. Significant impact on a critically endangered species, habitat or ecological community as defined by EPBC Act 1999 Policy Statement 1.1 Significant Impacts Guidelines.
Critical (5)	Major change to ecological structure and function through deterioration in water quality, geomorphic changes or habitat destruction/fragmentation, resulting in a reduction of between 25% and 40% in the regional occurrence of any habitat or resulting in a species having an overall reduction of over 60% as a result of direct or indirect impacts from the Project. Significant impact on an endangered or vulnerable species, habitat or ecological community as defined by EPBC Act 1999 Policy Statement 1.1 Significant Impacts Guidelines.
Major (4)	Moderate to major change to ecological structure and function through deterioration in water quality, geomorphic changes or habitat destruction/fragmentation, resulting in a reduction of between 15% and 25% in the regional occurrence of any habitat or resulting in a species having an overall reduction of between 40% and 60% as a result of direct or indirect impacts from the Project. Significant long term impact on species, habitat or ecological communities listed under other state and international legislation, such as the Nature Conservation (Wildlife) Regulation 2006 or IUCN red list.
Serious (3)	Moderate disturbance to ecological structure and function through deterioration in water quality, geomorphic changes or habitat destruction/fragmentation, resulting in a reduction of between 10% and 15% in the regional occurrence of any habitat or resulting in a species having an overall reduction of between 25% and 40% as a result of direct or indirect

Classification	Consequence
	impacts from the Project. Significant short term (but no lasting) impacts on species, habitat or ecological communities listed under other state and international legislation, such as the Nature Conservation (Wildlife) Regulation 2006 or IUCN red list.
Moderate (2)	Minor to moderate disturbance to ecological structure and function through deterioration in water quality, geomorphic changes or habitat destruction/fragmentation, resulting in a reduction of between 5% and 10% in the regional occurrence of any habitat or resulting in a species having an overall reduction of between 10% and 25% as a result of direct or indirect impacts from the Project. Potential long term changes to species, communities or habitats of low environmental value.
Minor (1)	Minor, none or positive impacts to ecological structure and function through changes in water quality, geomorphology or habitat availability, resulting in a reduction of less than 5% in the regional occurrence of any habitat or resulting in a species having an overall reduction of less than 10% as a result of direct or indirect impacts from the Project. Potential short term changes to species, communities or habitats of low environmental value.

3.1 Habitat reclamation

3.1.1 Impact assessment

Construction of the Australia Pacific LNG Facility near Laird Point will require the reclamation of approximately 2.4 hectares of mangroves and 24 hectares of saltpan/saltmarsh. The area of mangroves represents 0.03% of the estimated mangrove cover, and 0.5% of the saltpan/saltmarsh habitat in the Port Curtis region. The site boundaries for the LNG Facility have been chosen to minimise the removal of mangrove habitat in particular. A large stand of mangroves and a small mangrove-lined creek in the centre of the proposed project is proposed to be left undisturbed.

The reclamation of habitat for the construction of the LNG Facility is predicted to pose a “Medium” risk (“serious” consequence rating but “highly unlikely” ’likelihood rating) to the Port Curtis marine environment.

3.1.2 Mitigation and offsets

For the marine fish habitat that is to be disturbed, consideration of mitigation and offsets are guided by the State government Fish Habitat Management Operational Policy FHMOP (2002) *Mitigation and Compensation for Works or Activities Causing Marine Fish Habitat Loss*.

The objectives of this Policy are:

- To maintain fisheries values, including fish habitat values;
- To seek to ensure the costs associated with fish habitat losses attributed to public or private works are matched with, or are less than, a level of mitigation and/ or compensation appropriate to the disturbance of fish habitat;

- To promote maintenance of marine fish habitats through implementation of mitigation or compensation to meet the objective of No Nett Loss of Marine Fish Habitat Policy;
- To recognise the natural capital of fish habitats; and
- To create public awareness of the value of fish habitats.

With respect to the construction of the LNG Facility, losses of vegetated fisheries habitat are unavoidable, and as such compensation mechanisms need to be considered. The policy identifies that compensatory measures include in-kind and financial support for one or more of the following:

- Research projects
- Community based initiatives (e.g. Seagrass Watch)
- Restoration/rehabilitation projects
- Signage or educational materials for marine fish habitat information/management; or
- Enhancement of fishing access for the community (fishing platforms).

Compensatory activities may be carried out off-site but in the region where the disturbance is occurring, or may be part of a “Statewide Compensation Program”. Australia Pacific LNG have investigated a number of compensatory options for marine fish habitat loss. Australia Pacific LNG have consulted widely with local fishing stakeholders on offset options and have identified a preference for offsets at the local/regional level as it is the local/regional stakeholders that will potentially be impacted by the proposal. The specific options that have been considered to date include the following:

- Restoration and/or rehabilitation of “like for like” habitats in the Gladstone region
- Creation of purpose built inshore artificial reefs which also serve to mitigate loss of fishing access
- Financial and in-kind support for fish and habitat monitoring through recreational fishing groups specifically CapReef, and
- Financial and in-kind support for fish habitat research projects.

In terms of habitat restoration, Australia Pacific LNG has considered options in the Port Curtis region but has not identified any areas where restoration is necessary or likely to be effective. Australia Pacific LNG has considered options proposed in the Port Alma region to improve connectivity of saltmarsh/saltpan habitat to assist barramundi recruitment, but considered it too far removed from the project location, in addition to there being significant uncertainties regarding feasibility.

Australia Pacific LNG has considered the creation of inshore artificial reefs using purpose built materials to in part offset habitat loss, but principally to offset loss of recreational fishing access. “Reef Balls” are a commonly used material, but other structures can also be used. The deployment of artificial reefs has been used by DERM to mitigate loss of fishing access through marine park planning. Artificial reefs have been deployed and continue to be deployed for recreational fisheries enhancement in NSW. No specific location for an artificial reef in the Port Curtis region has been identified, however it is recommended that Australia Pacific LNG commits to further investigation of inshore artificial reefs if the community desire for these is strong.

CapReef is a community program monitoring the status of fish resources and the use of fish habitat in Central Queensland. CapReef is a partnership between government agencies, researchers and fishing groups with a strong community focus. It is recommended that Australia Pacific LNG provides

resources for programs such as CapReef to undertake relevant components of monitoring associated with fisheries and fisheries habitats.

At the current time however, Australia Pacific LNG has not finalised all options for offsetting the loss of marine fisheries habitat, but it is recommended that Australia Pacific LNG continue to work through the options with stakeholders and relevant agencies to implement activities that effectively compensate for loss of marine habitat.

3.2 Boat strike

3.2.1 Impact assessment

When vessel based activities overlap with habitats utilised by dugong and marine turtles they are at particular risk from boat strike which can cause significant injury or mortality. Marine turtles and dugong are vulnerable to boat strikes when they are at the surface breathing and resting between dives. It is commonly accepted that vessel speed and water depth are the main factors affecting the risk of boat strikes with faster vessels in shallower water posing a greater risk. Annually, boat strike is one of the most significant known causes of human-induced dugong mortality (Greenland and Limpus 2008).

There is current scientific evidence suggesting that death and injury caused by boat strike has a significant impact on dugong populations in Queensland (Grech and Marsh 2008). A recent study has found that the reaction time of dugongs does not change in accordance with the speed of an approaching vessel and therefore faster moving vessels have a greater probability of causing dugong mortality (Hodgson 2004).

For the Australia Pacific LNG project slow moving vessels such as tugs, barges, and LNG shipping itself is considered to pose an inherently low risk of boat strike to dugong and marine turtles in Port Curtis. Any fast ferries however are considered to pose an inherently medium risk (“serious” consequence rating but “possible” ’likelihood rating) to dugong and marine turtles from boat strike in Port Curtis.

3.2.2 Mitigation

Boat speed limits in key locations where dugong and marine turtles consistently frequent are the recognised approach to mitigating the risk boat strike poses to dugong. Boat speed limits are believed to reduce risks in three primary ways: greater reaction time for boat operators to locate animals and to identify the risk of animal collision; greater reaction time for marine mammals to recognise the presence of vessels and more time to get out of the way, and reduced severity of injuries in the event of boat strike (Hodgson 2004). In addition, vessels should utilise predefined and regular routes to reduce the spatial scale of disturbance, and only alter this route for marine safety reasons or if instances of interactions are considerable. Depending on the exact design of the ferry to be used propeller guards should also be considered.

With mitigation in place, any fast ferries activities that service the LNG Facility during the construction and operational phases of the development are considered to still pose a medium risk (“serious” consequence rating but “unlikely” ’likelihood rating) to dugong and marine turtles in Port Curtis from boat strike. However, it is problematic to consider mitigation for this risk in isolation of other current and proposed fast transport activities within the Port of Gladstone. It is recommended that Australia Pacific LNG continue to work with relevant government agencies and other industries that are, or proposing to operate fast transport activities to develop mitigation approaches that are practical.

3.3 Underwater noise

3.3.1 Impact assessment

Activities associated with construction in the marine environment and operations, in particular vessel movements, have the potential to displace dugong and cetaceans from critical habitat and interrupt critical behaviours through the creation of underwater noise. A number of marine mammal species, particularly cetaceans, have sensitive hearing and rely heavily on sound for communicating, navigation and locating prey (Gordon and Moscrop 1996).

Marine mammals have been found to avoid some human sound sources for ranges of several kilometres, abandoning valuable habitat in the process (Tyack, 2008). Jefferson et al. (2009) reviewed impacts and potential mitigation measures of coastal development on small cetaceans including the Indo-Pacific humpback dolphin (*Sousa chinensis*). There are a number of sources of impact on cetaceans associated with the proposed project including pile driving and vessel traffic.

Percussive piling for the construction of the MOF jetty is most likely to be of a frequency that will cause disturbance to dolphins. While information is limited, Jefferson et al. (2009) identified that Indo-Pacific dolphins avoid areas during pile driving but return once construction ceases. Elsewhere in Australia these dolphin species co-exist with coastal development including extensive port facilities (Hale et al. 1998). The most important area for Indo-Pacific dolphins in Moreton Bay is the Port of Brisbane (Hale et al. 1998). Indo-Pacific humpback dolphins and Australian snubfin dolphins are also associated with port infrastructure at Cleveland Bay, Townsville (Parra 2006). Bottlenose dolphins also inhabit inshore areas where significant amounts of recreational vessel and commercial water-based activities occur including Moreton Bay (Chilvers et al. 2005), Richmond and Clarence Rivers (NSW) (Fury and Harrison, 2008) and Port Stephens and Jervis Bay (NSW) (Möller et al. 2002). Overall, it is considered that disturbance to dolphins will occur during the construction phase as a result of pile driving, however, dolphins will utilise the area once construction activities cease.

Noise generated by vessel activity can also change the behaviour of dugong and result in alienation from important habitat. Potential energetic costs of boat disturbance to dugongs include: a reduction in energy intake, the energy expended while moving, and the possible cost of moving to a different patch on the seagrass beds. Disturbed dugongs may be forced to spend time searching for alternative feed patches and may be forced to feed on less desirable patches with lower nutritional value. Hodgson (2004) found that dugongs were less likely to remain feeding if a boat passed within 50 metres than if it passed at a greater distance. These movements occurred in response to boats passing at all speeds, and at distances of less than 50m to over 500m. Such disruptions to feeding can affect the health of a population if they occur at significant levels. However, if animals can move to suitable nearby habitat then this may largely mitigate impacts from disturbance (Gill et al. 2001). In the case of Port Curtis, existing high value dugong (seagrass) habitat occurs in areas unaffected by the current development.

Overall the inherent risk to cetaceans and dugong from underwater noise is considered severe.

3.3.2 Mitigation and monitoring

To mitigate the impact, Jefferson et al. (2009) identify that the use of “bubble curtains and jackets” can be effective. A bubble curtain is created by forcing air from compressors into a perforated rubber hose anchored to the bottom. The bubble curtains function by reducing the distance over which percussive sounds from activities such as pile driving are evident.

The use of mitigating technology along with applying “soft starts” to pile driving will be implemented. Soft starts refer to the increasing of pile energy gradually over a period of time.

The use of these mitigation measures reduce the risk to cetaceans and dugongs from underwater noise generated by aspects of the project to “medium” (“serious” consequence rating but “unlikely” ’likelihood rating). It is recommended that monitoring of the usage of the area adjacent to the LNG Facility by dolphins and dugong is undertaken prior, during and after construction. The principal aim of this monitoring is to determine if animals are displaced from habitat and whether this impact persists through time. If the impacts persist and are considered significant in terms of the viability of dugong and cetacean populations in Port Curtis, it is recommended additional corrective actions be undertaken.

3.4 LNG Facility lighting

3.4.1 Impact assessment

As discussed in Section 2.4.2, lighting impacts the sea-finding behaviour of marine turtle hatchlings and may also impact the use of nesting beaches by adult turtles. At Hummock Hill Island, the distinct lighting from the Boyne Island smelter which is approximately 18km north of that nesting beach was observed to disorientate nesting turtles (Hodge et al. 2006). However, only a very small change to the light regime (a distant glow) may be sufficient to alter marine turtle behaviour and it is not necessary for a line of sight from the light source to the turtle nesting beach.

Although the nearest nesting beach is in the vicinity of South End on Curtis Island, it is plausible that lighting from the operational LNG Facility will impact sea finding behaviour of hatchlings and the selection of nesting areas by adult flatback turtles. Confounding the assessment of the impact of lighting on marine turtles in this instance is that the light regime is already highly modified in the Gladstone area and will be further modified by future developments. Overall, lighting from the LNG Facility when constructed poses a medium risk (“major” consequence rating but “unlikely” ’likelihood rating) to the flatback turtle nesting area on South End on Curtis Island.

3.4.2 Mitigation

The benefits of managing light spill from the LNG Facility will have benefits to fauna other than marine turtles (e.g. birds).

The vegetated and undulating terrain of Curtis Island provides a significant vegetative lighting buffer between the LNG Facility and the flatback turtle nesting area. However, it is recommended that an approach to lighting that is consistent with minimising impacts on nesting marine turtles is adopted. No single solution, but rather a combination of solutions is necessary to mitigate light impacts on marine turtle nesting while allowing for safe and efficient construction and operation of coastal infrastructure. Both Witherington and Martin (1996) and Pendoley (2005) identify a suite of approaches that are applicable for this project to mitigating light impacts while maintaining a safe workplace. The approaches include the following:

- Physically shielding the lights and directing the lights onto work areas
- Lowering the height of lights
- Reducing the amount of reflective surfaces through the use of matt paints on surfaces where possible, and
- Use of motion detecting sensors and light timers.

Using long wavelength red, orange or yellow lights and avoiding short wave length white lights is considered effective at mitigating lighting impacts on nesting loggerhead turtles, but is not proven to be effective at mitigating impacts on flatback turtles and as such should not specifically be employed to mitigate the risk to flatback turtles. While these measure reduce the likelihood of lighting impacts on nesting adult and hatchling flatback turtles, the overall risk level remains at medium ("major" consequence rating but "highly unlikely" 'likelihood rating).

3.5 Fishing access

3.5.1 Impact assessment

With an influx of employees to the region for the project, the number of potential recreational anglers in the region will also increase. Approximately 45% of residents in the Fitzroy statistical division go recreational fishing at least once per year (Henry and Lyle 2003).

For safety reasons, the construction and operation of the proposed LNG Facility will result in a loss of fishing access to both commercial and recreational fisheries. Further, for the commercial net fishery, the provisions of the *Fisheries Regulations 2008* create an exclusion zone to mesh nets of 200m around any wharf or jetty.

Although not quantified, the area around the proposed LNG Facility is utilised by recreational anglers and to a lesser degree by commercial mud crabbers and net fisheries. It is not considered however, to be a prime location for any of these fishing activities. While commercial beam trawling is also licensed to operate within the Port Curtis region, available information suggests that the level of fishing effort throughout the region is low.

3.5.2 Mitigation and offsets

Australia Pacific LNG has shown through the stakeholder engagement process to date that it is committed to working with fishing stakeholders to minimise loss of fishing access. A number of options to offset loss of fishing access have been investigated, and these options have been considered in combination with those for addressing habitat loss. Australia Pacific LNG has consulted widely with fishing stakeholders to attempt to offset loss of fishing access. As well as further investigation of inshore artificial reef opportunities, it is recommended that Australia Pacific LNG consider providing support for the ongoing fish stocking activities at Awoonga Dam. It is also recommended that Australia Pacific LNG continue to consult with recreational fishing groups in the Gladstone region and relevant agencies to further investigate opportunities for recreational fishing offsets.

For possible loss of commercial fishing access, it is recommended that Australia Pacific LNG continues to consult with agencies and the industry on offset options.

3.6 Plankton entrainment

3.6.1 Impact assessment

Intake of saltwater for the desalination plant may result in the entrainment and mortality of plankton including fish and crustacean larvae of species of commercial and recreational significance. Some planktonic individuals may use their limited mobility and avoid the intake currents. The mortality of plankton entrained will be 100%.

It is not currently possible to predict the quantities of plankton entrained or the impact of the entrainment on the structure of assemblages in Port Curtis. However, given the volume of water likely to be entrained relative to the volume of Port Curtis and the high level of natural mortality among planktonic organisms, overall the impact is categorised as a “Medium” inherent risk.

3.6.2 Mitigation and monitoring

Overall strategies to reduce water demand and collect and use stormwater will reduce (but not remove) the overall need for desalinated water, and hence will reduce the volume of plankton that will be entrained. It is recommended that the intake is appropriately screened to prevent the intake of larger animals and the intake rate be as low as practical. It is not possible however to prevent the intake of all plankton. It is recommended that the intake of plankton is considered when designing the position of the seawater intake within the water column.

3.7 Desalination discharge

Water demand for the Australia Pacific LNG Facility during operations is primarily driven by the continuous demand for demineralised water required for the Acid Gas Removal Unit (AGRU). Potable water during construction and operation is also required. This water will be supplied through the operation of a seawater desalination plant which will process seawater sourced directly offshore of the LNG facility. Estimated water demand during construction and operation are shown in Table 3.2 and Table 3.3 respectively.

Table 3.2 Water demand during construction period

Requirement	Volume or rate
Hydrotest Water (Note 1)	160,000 m3
LNG Plant Concrete Work (Note 2)	40,000 m3
Site preparation/dust control	6,000 m3
Potable water (Note 3)	650,000 m3
Potable water demand rate (Note 3)	Varies from 1 to 35 m3/hr over construction period

Note 1:Based on largest tank and re-using water to test other tanks.

Note 2:Based on 0.214 m3 water per m3 of concrete.

Note 3:Based on peak manpower loading of 2,500 over 40 months and potable water demand of 0.284 m3/person/day excluding hydrotest water.

Table 3.3 Water demand during operations

Requirement	2 LNG Trains m3/h	4 LNG Trains m3/h
Treated Water Demand	0.8	1.6
Potable Water Demand (Note 1, 2, 3, and 4)	8.33	13.33
Laboratory Usage	1.2	2.4
Clinical Usage	1.0	2.0
Demineralised Water (Note 5)	13.34	26.7
Safety Showers	3.0	6.0
Fire Water Flush Demand (Note 6)	0.8	1.6
Total Water Demand	28.53	53.6
Add 20% Margin	5.71	10.7
Recommended Freshwater Demand	34.24	64.3
Total Seawater Intake to the Plant (Note 7)	85.6	160.8

Note 1: Based on per capita daily flow rate of 0.20 m3.
Note 2: 9.0 MTPA (2 Trains) requires 250 people in the plant daily.
Note 3: 18 MTPA (4 Trains) requires 400 people in the plant daily.
Note 4: Potable water demands are based on a peaking factor of 4.0.
Note 5: Demineralised water generation involves additional brackish water from desalination (BWRO) and Electrodeionisation (EDI) steps with an overall water recovery rate of 60%.
Note 6: Water demand for routine firewater testing are based on 30 monitors tested per train monthly for 5 minutes @ 114 m3/ hr.
Note 7: Seawater desalinaiton with the pretreatment system overall recovery rate is assumed 40%.

The below assessment considers the operational case (higher volume). Discharge scenarios and impacts on coastal processes are considered for both construction and operation in Attachment 12 which provides further details.

Desalination plants typically produce a hyper-saline brine (highly concentrated salty water) waste-stream, containing seawater constituents at around double their normal concentrations. Additionally, the waste-stream also contains small amounts of additives used for treatment and cleaning during the desalination process. Operation of the Australia Pacific LNG desalination plant will produce a brine waste-stream to be discharged into Port Curtis, at a rate of up to 130m^3/hr. This represents a maximum case which exceeds the brine discharge rate for the water demand summarised in Table 3-3. The likely end-of-pipe concentrations of brine stream constituents are provided in Table 3.4.

Table 3.4 Likely end-of-pipe concentrations of brine stream constituents from the proposed Australia Pacific LNG desalination plant at Port Curtis.

Characteristic	Estimated discharge value
pH	6.0 – 8.0
TSS (mg/L)	20 – 40
Calcium (Ca) (mg/L)*	600 – 750
Magnesium (Mg) (mg/L)*	2,000 – 2,500
Potassium (K) (mg/L)*	600 – 800
Sodium (Na) (mg/L)*	19,000 – 22,000
Chloride (Cl) (mg/L)*	30,000 – 33,000
Flouride (F) (mg/L)	1.5 – 3
Sulfate (as SO4) (mg/L)*	4,000 – 6,000
Strontium (Sr) (mg/L)*	15 – 25
Chlorine (Cl) (mg/L)	<1 mg/L
Anti-scalant (mg/L)	8
Flocculent (mg/L)	5
Polymer (mg/L)	1
Silicon Dioxide (mg/L)	1 – 2
BOD5 (mg/L)	5 – 10

* Natural irons present in seawater – refer to http://www.seafriends.org.nz/oceano/seawater.htm and http://www.answers.com/topic/ocean-water, as is chloride.

The desalination process creates a brine discharge with seawater constituents at roughly double their normal concentrations and also introduces small amounts of additives used for treatment and cleaning during the process which have environmental impacts. As a consequence of the increased salinity, the brine discharge tends to be negatively buoyant and will tend to sink to the seabed under calm conditions. The Australia Pacific LNG desalination plant will use a variety of chemicals for cleaning and fouling management, coagulation of solids from wastewater, potabilisation of the drinking water and for control of microbiological fouling of membranes. Some of these chemicals, or chemical by-products derived from the chemicals used, will be discharged with the concentrated seawater.

A summary of likely chemical additives proposed for use in the Australia Pacific LNG desalination plant are shown in Table 3.5. It should be noted that the chlorine in the form of sodium hypochlorite will be dosed intermittently in the intake to control marine growth. A typical concentration for dosing with sodium hypochlorite at the seawater intake varies from 4 to 10mg/L. It has also been assumed that sodium bisulphite will be used to chemically reduce the sodium hypochlorite in the intake water, prior to membrane filtration.

Table 3.5 Chemical additives used in the desalination process

Stage in process	Additive	Process	Purpose	Treatment method
Intake	Sodium hypochlorite (4-10 mg/L)	Intermittent chlorination for shock dosing at the intake	Prevent marine growth in pipelines.	Total residual oxidant concentration (1) increased by 4-10 mg/L during intermittent shock chlorination periods at the intake; reduced to zero prior to discharge to ocean by the addition of sodium bisulphite.
Prior to Pre-treatment	Sodium bisulphite typically dosed at 200% of stoichiometric demand	Dechlorination	Remove chlorine prior to desalination membranes	The bisulphite will chemically reduce the sodium hypochlorite. Excess bisulphite will remove some oxygen from the seawater.
Pre-treatment	Polymer (Polyelectrolyte Pre-treatment)	Pre-treatment of the desalination feedwater	Removal of particulate matter	Polyelectrolytes are soluble in water and quickly and irreversibly bind to naturally occurring dissolved organic carbon and particulate material.
	Sulphuric acid and Citric acid	Chemical cleaning of desalination membranes	To clean membranes and restore filtration performance	Sulphuric and citric acid is used to remove calcium carbonate and iron deposits from the membranes during periodic cleaning sequences.
Desalination	Anti-scalant	Anti-scaling dosing of desalination feed	Prevents formation of membrane scaling	Anti-scalants are added to the feedwater after pre-treatment and prior to entering the desalination process.

(1) Total residual oxidant refers to Cl_2, HOCl, HOBr, hypochlorite ion (OCl^-) and hypobromite ion (OBr^-) in equilibrium.

Seawater will be drawn into the plant through an open intake to the intake pipeline and then to the seawater intake pump station. The intake system is subject to fouling by marine organisms which have the potential to restrict the intake flow rate. In order to control the level of fouling within the intake system, sodium hypochlorite solution will be intermittently dosed into the intake structure during plant operation. The dosing period is usually in the order of 60 minutes which results in a residual chlorine concentration of between four and ten mg/L. It is envisaged that this operation will be performed at weekly intervals. The sodium hypochlorite will be neutralised by the addition of sodium bisulphite solution with in the desalination process. The chlorination and subsequent neutralisation processes will marginally increase the sodium, chloride and sulphate ions concentration in the seawater feed to the desaliation plant. The process incorporates a very comprehensive control and monitoring system to ensure that no chlorine is present at the membranes.

The desalination system requires continuous addition of an anti-scalant. The anti-scalant is likely to be either phosphonic or carboxylic-rich polymers. The polymer will be rejected by the membrane and will be discharged in the brine stream to the ocean. The membranes will require periodic chemical cleaning at a rate of about twice per year. The cleaning solution will likely be an alkaline detergent that typically contains 500 mg/L of sodium hydroxide and between 250 mg/L and 500 mg/L of detergent.

Lime, carbon dioxide, chlorine (gas) and fluorosilicic acid are traditionally used in the potabilisation process. None of these chemical additions however, are usually discharged with the brine. Considering the end of pipe concentrations highlighted in Table 3.4, Table 3.6 presents the likely concentrations of desalination brine discharge components present in the receiving environment, following a dilution of 1:50, at a distance of 27m from the diffuser arrangement.

Table 3.6 Likely concentrations of desalination discharge components following a dilution of 1:50.

Characteristic	Estimated Discharge Value	Likely concentration at 1:50 Dilution
pH	6.0 – 8.0	7.0 – 8.0
TSS (mg/L)	20 – 40	N.A
Calcium (Ca) (mg/L)*	600 – 750	12 – 15
Magnesium (Mg) (mg/L)*	2000 – 2500	40 – 50
Potassium (K) (mg/L)*	600 – 800	12 – 16
Sodium (Na) (mg/L)*	19000 – 22000	380 – 440
Chloride (Cl) (mg/L)*	30,000 – 33,000	600-660
Flouride (F) (mg/L)	1.5 – 3	0.03 – 0.06
Sulfate (as SO4) (mg/L)*	4000 – 6000	80 – 120
Strontium (Sr) (mg/L)*	15 – 25	0.3 – 0.5
Chlorine (Cl-) (mg/L)	2000 – 5000	40 – 100
Anti-scalant (mg/L)	8	0.16
Flocculent (mg/L)	5	0.1
Polymer (mg/L)	1	0.02
Silicon Dioxide (mg/L)	1 – 2	0.02 – 0.04
BOD5 (mg/L)	5 – 10	N.D

* Natural irons present in seawater – refer to http://www.seafriends.org.nz/oceano/seawater.htm and http://www.answers.com/topic/ocean-water, as is chloride.

3.7.1 Impact Assessment

An impact assessment was carried out on the individual chemical additives, or their degradation products formed during the desalination process, that are likely to be in the brine stream discharged to

the receiving environment. The effects of salinity, which is usually the main constituent of a brine discharge that has an effect on laboratory reared marine species, was also examined. Salinity is defined as a physico-chemical characteristic and not a toxicant in the Australian and New Zealand Guidelines for Fresh and Marine Water Quality (ANZECC and ARMCANZ, 2000).

An assessment of the potential biological effects on the receiving environment from discharge of brine concentrate was developed from findings from an ecotoxicology literature review and relevant material safety data sheets. Ecotoxicology data are generally not available for organisms indigenous to waters surrounding the proposed diffuser outlet at Port Curtis. Therefore, data from the international literature, on both marine and (to a lesser extent) freshwater species were examined, as well as some data on native Australian species. For the purpose of this assessment, the anti-scalant assessed was a phosphonic polymer, which is the most widely used anti-scalent in desalination plants around Australia. The toxicity information reported in Table 3.7 relates to the parent chemical unless otherwise stated.

Table 3.7 Ecotoxicology literature review for chemical additives identified in the desalination waste stream

Chemical additive	Degradation product	Toxicity	Use/environmental fate
Sodium hypochlorite	Total Residual Oxidant	Marine fish: 2 spp, 48−96 h LC50 128−250 µg/L (2−8 h/day intermittent to continuous dosing). Chronic NOEC (7 d growth), *Menidia beryllina*, 87−186 µg/L.(1) Marine crustacean: 1 sp, *Mysidiopsis bahia*, 96-h LC50, 73−268 µg/L (2−8 h/day intermittent to continuous dosing). Chronic NOEC (7 d reproduction), *M. bahia*, 20−87 µg/L.(1) Freshwater crustacean: Freshwater crustaceans: 3 species of cladocerans, 24−48 h LC50, 12−160 µg/L. Two 48-h LC50 values were 5 and 6 µg/L, measured under continuous flow of test solution. Chronic NOEC, 10 d immobilisation *Ceriodaphnia dubia*, 48 µg/L (same as acute figures). (1)	Marine growth control. Total residual oxidant refers to Cl_2, HOCl, HOBr, hypochlorite ion OCl^- and hypobromite (OBr^-) in equilibrium. The relative amounts of the different forms in equilibrium are governed by pH, temperature and ionic strength(1)
Polymer flocculants	Remains as polymer (polyquaternary amines)	Flocculants appear to act mainly by acute toxicity, probably by physical blocking and mucous production of gill tissue and adsorption by small invertebrates. (1) Toxicity results range between 100 and 1,000,000 µg/L for fish. As acute effects are reported as low as 10 µg/L, polymer concentrations greater than 1 µg/L may cause environmental harm. (2)	Binds to naturally occurring particulate material in seawater. Polyectrolyte polymer typically used consist of 9-20% N (by weight) and are usually not toxic. May contribute a small additional nitrogen load to the receiving environment. The form of N in these types of polymer are not biologically available as it is chemically inert and bound to flocs (8)
Sulphuric acid	Dissociates into hydronium and sulphate ions	48 h LC50 Flounder 100 to 330 mg/L; 48 h LC50 Shrimp 80 to 90 mg/L; 48 h LC50 Prawn 42.5 ppm. This material may be toxic to aquatic life. (2)	Used for cleaning MF membranes and neutralisation of alkaline waste solutions.

Chemical additive	Degradation product	Toxicity	Use/environmental fate
Sodium bisulphite	Sodium and sulphate ions	For sodium sulphate, a range of toxicity data exists. A selection of the lowest effects concentrations includes: Algae were shown to be the most sensitive to sodium sulfate; EC50 120h = 1,900 mg/L. For invertebrates (*Daphnia magna*) the EC50 48h = 4,580 mg/L; and fish appeared to be the least sensitive with a LC50 96h = 7,960 mg/L for *Pimephales promelas* (3) Sea squirt, *Ascidiella scabra*, 24 h LC50 6,400 mg/L (5)	Used for dechlorination i.e. removal of oxidant residual by reducing oxidants. Residual free chlorine in the feedwater will be removed within the desalination system by dosing with sodium bisulphite. This neutralisation process ultimately produces sodium, chloride and sulphate ions which are common in seawater.
Anti-scalant (phosphinocarboxlic acid)	Carbon dioxide and phosphorus oxides	Phosphinocarboxylic acid: zebrafish: 96 hr LC50 >1000 mg/L. (5) Toxicity of anti-scalants is relatively low. In seawater, the complexing properties of anti-scalants, which are important for inhibiting scale formation, could interfere with natural element cycles. Metal complexes are generally less available for marine organisms than dissolved metal ions, so that uptake of essential nutrients (e.g. iron) or toxic heavy metals (e.g. copper) could be reduced. (6)	Prevent scale formation on membranes. Usually polymeric substances: either polyphosphates, phosphonates, polymaleic acids or polyacrylic acids(6) Some eutrophication related issues have been identified with use of polyphosphates. Toxicity of anti-scalants is relatively low with slow biodegradation rates(6)
Citric acid	Citrate	The product itself and its products of degradation are not toxic. (7)	Organic acid used for membrane cleaning. Hazardous short-term degradation products are not likely. However, long-term degradation products may arise. (7)

(1) Referenced from ANZECC/ARMCANZ (2000). (2) Material Safety Data Sheet (MSDS) referenced from J.T.Baker. (3) UNEP Publications.http://www.inchem.org/documents/sids/sids/7757826.pdf; (1973). (4) Robinson and Perkins (1977). (5) http://www.gulfengineering.com/msds/wm_msds/g103%20msds.pdf. (7) MSDS referenced from Science Lab. (8) Accepta 2058 MSDS. PolyDADMAC Water and Wastewater Treatment. www.accepta.com. (9) Accepta 2058 MSDS. Pulp and Paper. www.accepta.com. (10) Material Safety Data Sheets. Ciba Specialty Chemicals PLC, 1998.

3.7.2 Salinity

The brine to be discharged is calculated to have a salinity of up to 67.5ppt (ppt = g/kg) at the point of discharge. This salinity is approximately 1.9 times the concentration in background seawater, which is normally between 35–37ppt. A minimum dilution of 1:50 at a distance of 27m from the diffuser arrangement should achieve an effective salinity at that distance of around 38ppt or less for the majority of the time. Similarly, the major irons, such as sodium, sulphate, magnesium, calcium, chloride will all be present at concentrations below background conditions wihtin 27 m from the diffuser arrangement. Modelling results and details of the diffuser location and design are provided in the Coastal Processes Study report (see Attachment 29).

An extensive literature review was conducted to understand impacts of a brine discharge on the marine environment. The primary concern regarding salinity impacts to organisms relates to physiological changes resulting from osmotic effects. Water will generally pass through membranes from a less concentrated environment to a more concentrated environment, and in the context of marine organisms exposed to hypersaline waters could affect their health by dehydration and associated impairment.

Salinity outside (either higher or lower) of the tolerance range of organisms causes osmoregulatory stress. However, salinity can also be a modifier of toxicity. It generally decreases the toxicity of other toxicants (Chapman et al. 2001), such as some metals and organics, by decreasing their solubility (i.e. the 'salting out effect'),.

Most of the existing literature investigating salinity toxicity is focused on rising salinity in freshwater environments (e.g. Kefford et al. 2003; 2004) and changes in osmoregulatory ability under exposure to high heavy metal concentrations (Jones 1975). Salinity tolerances for a range of marine fauna are described in the literature, however much of this relates to tolerance of reduced salinities rather than increased salinities, or hypersaline conditions. Nonetheless, some information is available across a broad range of faunal groups and is summarised in Table 3.7. It is recognised that a number of the species identified in Table 3.7 are not found in Australia waters; however the information provides general information on salinity tolerances across faunal groups and also provides an indication of potential sensitivities within these groups.

Salinity tolerances reported for a range of Australian marine species include the scallop, *Pecten fumatus* (25-40 g/L), the pipi, *Plebidonax deltoides*, the flat oyster, *Ostrea angasi* (20-45g/L), the blue mussel *Mytilus edulis planulatus* and the Sydney cockle *Anadara trapezia* (15-45g/L) (Nell and Gibbs, 1986). It is apparent from this that some marine species can tolerate a wide range of salinity changes. Further, the upper threshold concentrations are all greater than the 38g/L maximum concentration predicted at up to 27 m from the diffuser arrangement. As previously mentioned, the negative buoyancy of the plume will cause the brine to sink to the seabed under calm conditions, however, hypersaline conditions will be non–existent within 27 m, under these low velocity conditions. It is therefore expected that salinity will not cause unacceptable changes to environmental values beyond a distance of 27 m from the point of discharge.

3.7.3 BOD

When large amounts of biomass are degraded by bacteria, the biological oxygen demand (BOD) of the bacteria can deplete the oxygen concentration in the water leading to severe events like fish kills (ANZECC/ARMCANZ, 2000). Low DO concentrations can also result in adverse effects on many aquatic organisms (e.g. fish, invertebrates and microorganisms) which depend upon oxygen for their

efficient functioning. The D.O in the receiving environment should not be permitted to fall below 60% saturation (ANZECC/ARMCANZ, 2000).

Given that the receiving environment within Port Curtis is a well flushed tidal environment, and considering the efficiency of the proposed diffuser arrangement, it is highly unlikely that any far field impacts will be experienced from the BOD loads discharged within the brine. Dissolved oxygen levels are expected to be at saturation levels within 27 m from the diffuser arrangement.

3.7.4 Suspended solids

The expected end-of-pipe concentrations of 20–40mg/L of suspended solids are greater than the QWQG threshold of 15 mg/L (DERM, 2009). It is expected that other processes such as naturally-occurring flocculation will further reduce the likely concentration of discharged suspended solids with distance from the discharge point. The discharge concentrations are comparable to upper turbidity levels measured in deep waters during the dry season (95th percentiles from 11 to 35 NTU (GHD, 2009) and median turbidity values measured in shallow water sites during the wet season, ranging between 10 and 23 NTU (GHD, 2009).

Suspended solids should be monitored within the vicinity of the diffuser during operation of the brine outfall, to manage potential smothering and the affects of increased light attenuation in the water column on sensitive marine receptors. To mitigate impacts from high suspended solids loads on the marine environment, it is recommended to redirect any waste materials collected off screens and desalination filters to land fill, rather than into the brine stream discharged into the marine environment.

3.7.5 Sodium hypochlorite

Chlorine in the form of sodium hypochlorite will be dosed intermittently in the intake to prevent marine growth on the internal wall of the intake pipe. Sodium hypochlorite is expected to be dosed at between 4mg/L and 10mg/L (reported as chlorine) at the intake structure as is the common practice in other Australian desalination plants. Cleaning solutions with chlorine concentrations up to 500mg/L may also be used in the pre-treatment process to chemically clean the membranes.

In seawater, the reaction of chlorine with bromine results in the formation of chloride ion and hypobromous acid (HOBr) (ANZECC/ARMCANZ, 2000). Chlorine degradation products are often referred to as total residual oxidants (TRO), which consist of Cl_2, HOCl, hypochlorite ion (OCl^-) and HOBr, hypobromite (OBr-) in equilibrium, where the relative amounts of the different forms in equilibrium are governed by pH, temperature, salinity and ionic strength.

Sodium hypochlorite (from shock dosing of the intake structures) is normally neutralised with sodium bisulphite before entering the desalination process. Similarly, spent hypochlorite cleaning solutions in such circumstances is usually dosed with sodium bisulphate solution to reduce the oxidant to below detection levels.

Residual oxidant concentrations have been predicted at 40 – 100 mg/L, at 27m from the diffuser arrangement. This concentration at the edge of the mixing zone is predicted to be significantly above the value of 3 µg Cl/L set by ANZECC/ARMCANZ (2000) as a low reliability marine trigger for total residual chlorine in the marine environment. ANZECC/ARMCANZ (2000) notes however, that this value should only be used as an indicative interim working level. The minimum concentration reported to influence toxicity was reported in the marine crustacean *Mysidiopsis bahia*, with a NOEC of 20 µg/L. This concentrations predicted at the edge of the mixing zone are more than three orders of magnitude higher than the NOEC levels reported in Table 3.7.

It is recommended to treat all of the residual chlorine to ensure there is zero discharge of any disinfection agents discharged into the surrounding marine environment. This process of dechlorination will also reduce the likelihood that chlorination by-products are formed. As long as the Australia Pacific LNG desalination plant will be dechlorinating the water used to control marine growth prior to discharge, there are unlikely to be any significant impacts on the receiving environment from discharge of residual oxidants present in the brine waste stream.

3.7.6 Polyelectrolytes (Polymers)

For the Australia Pacific LNG desalination plant, it is expected that a polymer will be added to the wastewater clarifier. The polymer is likely to be a high molecular weight flocculant. Polymers are soluble in water and quickly and irreversibly bind to naturally occurring dissolved organic carbon and particulate material. Acute toxicity (LC50 values) reported for polymers ranges between 100µg/L and 1,000,000µg/L for marine fish (ANZECC/ARMCANZ, 2000). For the desalination facility, the residual concentration for these compounds is expected to be around 1mg/L. Likely concentrations at a distance of 27m from the diffusers were calculated to be no greater than 20µg/L, which is below the lowest reported acute toxicity value of 100µg/L. The risk of these additives resulting in unacceptable changes to environmental values beyond 27m from the diffuser arrangement is considered negligible.

3.7.7 Sodium bisulphite

The derivatives from sodium bisulphite reaction with chlorination associated with the intake system will increase the salinity of the brine stream by up to 40mg/L for a short duration every week. The salinity increase is due to increased concentration of sodium, chloride and sulphate ions. Sodium bisulphite is usually added in excess of the stoichiometric demand and the excess chemical will remove approximately 2mg/L of oxygen from the brine steam before it is introduced into the ocean.

Sodium bisulphite is also commonly used to neutralise chlorine in the spent chemical cleaning streams associated with the membrane filter. The end products of this reaction are sodium, chloride and sulphate ions contained in a background sodium chloride solution. When this solution is dosed into the brine stream it has the effect of lowering the ion concentration in the brine before it is introduced into the ocean. Considering the comparatively low concentrations of sodium bisulfite derivatives discharged into the receiving environment, it is unlikely that these derivatives will result in any impacts on the receiving marine environment surrounding the diffuser outlet.

3.7.8 Sulphuric acid

Sulphuric acid is used for desalination membrane cleaning and to adjust the pH of alkaline waste. The end product associated with the use of sulphuric acid is the sulphate ion at a neutral pH. The pH corrected cleaning solutions are pumped into the brine stream and this has the effect of reducing the concentration of the sulphate ion discharged into the ocean. All end products resulting from the addition of sulphuric acid are benign and present no adverse environmental impact.

3.7.9 Anti-scalant (phosphinocarboxylic acid)

Anti-scalants are added to feedwater after pre-treatment to reduce scaling on the desalination membranes. The anti-scalant likely to be used at the desalination facility is a phosphonate–based compound. The expected maximum anti-scalant concentration in the brine stream is 8mg/L. Likely maximum concentrations of anti-scalant at 27m from the diffuser arrangement will be up to 160µg/L for the 1:50 dilution.

The predicted concentrations in the receiving environment are considerably lower than the 96 h LC50 value reported for the zebrafish of >1000 mg/L. Toxicity of anti-scalant is considered to be relatively low. The risk from residual phosphonate-based anti-scalant to the receiving environment is considered low.

3.7.10 Citric acid

Citric acid is used periodic cleaning sequences to remove calcium carbonate and iron deposits from the membranes. The product itself, and its products of degradation, are not considered toxic. The concentrations of the cleaning solutions will be significantly diluted and all wastewater will be neutralised before entering the brine outflow, hence no resulting impacts to the marine receiving environment are anticipated from the use of citric acid.

3.7.11 Summary of impacts

The brine impact assessment has identified the toxicological risks posed by all known compounds in the desalination effluent from the Australia Pacific LNG Desalination Plant that could be considered as contaminants to the receiving marine environment in the vicinity of the discharge location. The assessment was based on a review of existing information and a limited number of assumptions regarding operational performance of the desalination plant.

Residual oxidant concentrations (chlorine and disinfection by-products) have been predicted to be more than three and four orders of magnitude higher than the chronic NOEC values, and ANZECC/ARMCANZ (2000) low reliability trigger value, respectively, at the edge of the mixing zone. It is recommended to treat all of the residual chlorine to ensure there is zero discharge of any disinfection agents into the surrounding marine environment. This process of dechlorination will also reduce the likelihood that chlorination by-products are formed. As long as the desalination plant will be dechlorinating the water used to control marine growth prior to discharge, there are unlikely to be any significant impacts on the receiving environment from discharge of residual oxidants or any other residual contaminants present in the brine waste stream.

This assessment has only examined the contaminants identified in the brine discharge (Australia Pacific LNG, 2009). Any changes to the desalination process and/or constituents used in the desalination process should be examined and the impact assessment updated accordingly. It is recommended to maintain a register of all chemicals added to the desalination process and likely to be discharged to the receiving environment. This register should include the dose rate and load of the addition and a copy of the MSDS for the additive. Assessment should be made of the likely loss and/or removal of any additive during the desalination process and the resulting concentration in the discharge. Where environmental toxicity is indicated by the MSDS, the impact assessment undertaken here should be revised to consider the new chemical.

3.7.12 Mitigation and monitoring

An appropriately located outfall and diffuser design will assist in the mixing of the discharge with the ambient seawater. It is recommended that Australia Pacific LNG optimise the diffuser design and location to minimise the scale of the impact from the discharge. Approaches to reduce water demand and to ensure freshwater is used efficiently throughout the plant will reduce freshwater demand and hence the desalination brine volume. The waste material collected from screens and desalination filters should be re-directed to landfill, to avoid high suspended solids concentrations in the brine stream.

To reduce uncertainty regarding actual as opposed to predicted risks from the discharge on the marine environment, it is recommended that WET testing is undertaken pre-commissioning, post-commissioning and then annually during operational activities.

A baseline water quality monitoring program prior to plant commissioning is also recommended to gain an understanding of site specific water quality conditions. In instances when water quality parameters are found to exceed QWQG WQO's and ANZECC/ARMCANZ trigger values, site specific water quality objectives shall be derived and applied post-commissioning, This may be applicable to nutrient parameters, given that nutrient concentrations in Port Curtis have been previously reported as elevated above QWQG objectives and ANZECC trigger values (GPC, 2009).

An operational water quality monitoring program should be implemented post-commissioning which includes the following:

- A plume validation study, to validate the near field and far field modelling performed;
- Conduct routine in-pipe testing for the contaminants and physico-chemical properties addressed within this marine impact assessment and in accordance with any DERM permit requirements;
- When concentrations are reported above DERM permit discharge limits in-pipe, the fate of those chemicals/physical properties in the receiving environment should be investigated through relevant approaches as follows:
  - Investigate the predicted concentrations in the receiving environment, using the diffuser modelling and plume validation study. When a predicted concentration exceeds the EPA (2007a) WQO's or relevant ANZECC trigger values at the boundary of the approved toxicity zone (proceed to step 2);
  - Measure actual concentrations of the contaminant/s of concern in the receiving environment, at or near the approved mixing zone boundary. Water column profiling of salinity should also be conducted to examine actual dilution of the brine. Results from this profiling will assist in understanding likely residual contaminant concentrations prior to receipt of laboratory test results. If the measured concentrations exceed the respective WQO's or trigger limits (proceed to step 3);
  - Compare measured concentrations with background concentrations at key reference sites. If the measured concentrations at or near the boundary of the approved mixing zone exceed background concentrations (proceed to step 4);
  - Undertake Direct Toxicity Assessment (for elevated toxicants). The DTA is undertaken by sampling the brine in-pipe, to determine the likely extent of any toxicity effects beyond the approved mixing zone boundary. If toxicity is considered likely beyond the approved toxicity zone and there is uncertainty regarding the contaminant/s causing the observed toxicity (proceed to step 5);
  - Implement a Toxicity Identification Evaluation to determine the contaminant/s likely to be causing toxicity beyond the approved mixing zone boundary. Other studies, such as sediment and biota (infauna) investigations may be necessary to examine whether the potential toxicity is impacting on the Port Curtis marine environment.

As part of a receiving environment monitoring program, it is recommended to monitor potential smothering and reductions in light attenuation in the water column, within the vicinity of any marine environmental receptors. No seagrass is currently present on the northwest side of Curtis Island,

however, consideration should be given to the results of the annual seagrass surveys undertaken by DPI&F and if seagrass is detected, it should be managed accordingly.

4. Conclusion and recommendations

The proposed location for the LNG Facility is in the vicinity of Laird Point which is within the Gladstone Harbour Port limits and within the Great Barrier Reef World Heritage Area. The existing environment at Port Curtis has been described using up to date information largely drawn from the peer-reviewed literature. The area at and adjacent to the proposed LNG plant contains examples of high value marine habitat – particularly saltmarsh/saltpan and mangrove habitats. Seagrass habitat is found around Channel Island. No coral reef habitat is present. Port Curtis provides habitat for marine species of conservation significance including dugong, inshore dolphins and marine turtles. Directly and indirectly Port Curtis also supports recreational and commercial fisheries.

A number of potential impacts from the construction and operation of the proposed LNG plant and associated infrastructure have been identified and include:

- Discharges from the desalination plant including brine
- Entrainment of plankton in seawater intake
- Boat strike on dugong and marine turtles
- Underwater noise, and
- Lighting impacts on marine turtles.

It is recommended that Australia Pacific LNG ensure that environmental stewardship is effectively applied throughout the construction and operation phases of the project. A considerable amount of planning and consultation work has also been undertaken prior to the environmental assessment stage to identify and minimise potential impacts. In summary recommendations for the project are as follows:

- To reduce impacts on marine mammals, investigate sound mitigating technology such as utilise bubble curtains to reduce underwater noise generated by pile driving activities and “soft starts” to pile driving activities.
- Monitor dolphin usage of the area during and post construction.
- Where appropriate, adopt “turtle friendly” lighting approaches as a component of an overall approach to reduce lighting spill, including: physically shielding the lights and directing the lights onto work areas; lowering the height of lights; reducing the amount of reflective surfaces through the use of matt paints on surfaces where possible; and, use of motion detecting sensors and light timers.
- Continue to work through options with stakeholders and relevant agencies to achieve an appropriately high level outcome from activities aimed at offsetting loss of marine habitat and loss of fishing access.
- Speed limits for ferry services and designated ferry routes that consider both operational requirements of the port and other port users, and the need to avoid key marine mammal and marine turtle habitat.
- Monitor the recovery of benthic macro-invertebrate assemblage in the area to be dredge for the approach channel to the MOF using before-after-control-impact comparisons.
- Utilise the programs such as the CapReef group to undertake community monitoring of fisheries and fisheries habitat pre and post construction.

- For the desalination brine discharge, utilise an appropriately designed and deployed diffuser arrangement that reduces the spatial scale of the impact from the discharge.

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Appendix A Great Barrier Reef World Heritage values

The Great Barrier Reef was inscribed on the World Heritage List in 1981. The World Heritage criteria against which the Great Barrier Reef was listed remain the formal criteria for this property. The World Heritage criteria are periodically revised and the criteria against which the property was listed in 1981 are not necessarily identical with the current criteria.

Criteria

Outstanding example representing a major stage of the earth's evolutionary history.

The Great Barrier Reef is by far the largest single collection of coral reefs in the world. The World Heritage values of the property include:

- 2904 coral reefs covering approximately 20,055km squared
- 300 coral cays and 600 continental islands
- Reef morphologies reflecting historical and on-going geomorphic and oceanographic processes
- Processes of geological evolution linking islands, cays, reefs and changing sea levels, together with sand barriers, deltaic and associated sand dunes
- Record of sea level changes and the complete history of the reef's evolution are recorded in the reef structure
- Record of climate history, environmental conditions and processes extending back over several hundred years within old massive corals
- Formations such as serpentine rocks of South Percy island, intact and active dune systems, undisturbed tidal sediments and "blue holes"; and
- Record of sea level changes reflected in distribution of continental island flora and fauna.

Outstanding example representing significant ongoing geological processes, biological evolution and man's interaction with his natural environment.

Biologically the Great Barrier Reef supports the most diverse ecosystem known to man and its enormous diversity is thought to reflect the maturity of an ecosystem, which has evolved over millions of years on the northeast Continental Shelf of Australia. The World Heritage values include:

- The heterogeneity and interconnectivity of the reef assemblage
- Size and morphological diversity (elevation ranging from the sea bed to 1142m at Mt. Bowen and a large cross-shelf extent encompass the fullest possible representation of marine environmental processes)
- On going processes of accretion and erosion of coral reefs, sand banks and coral cays, erosion and deposition processes along the coastline, river deltas and estuaries and continental islands
- Extensive *Halimeda* beds representing active calcification and sediment accretion for over 10,000 years
- Evidence of the dispersion and evolution of hard corals and associated flora and fauna from the "Indo-West Pacific centre of diversity" along the north-south extent of the reef

- Inter-connections with the Wet Tropics via the coastal interface and Lord Howe Island via the East Australia current
- Indigenous temperate species derived from tropical species
- Living coral colonies (including some of the world's oldest)
- Inshore coral communities of southern reefs
- Five floristic regions identified for continental islands and two for coral cays
- The diversity of flora and fauna, including:
  - Macroalgae (estimated 400-500 species)
  - Porifera (estimated 1500 species, some endemic, mostly undescribed)
  - Cnidaria: Corals - part of the global centre of coral diversity and including:
  - Hexacorals (70 genera and 350 species, including 10 endemic species)
  - Octocorals (80 genera, number of species not yet estimated)
  - Tunicata: Ascidians (at least 330 species)
- Bryozoa (an estimated 300-500 species, many undescribed)
- Crustacea (at least 1330 species from 3 subclasses)
- Worms:
  - Polychaetes (estimated 500 species)
  - Platyhelminthes: include free-living Tubelleria (number of species not yet estimated), polyclad Tubelleria (up to 300 species) and parasitic helminthes (estimated 1000's of species, most undescribed)
- Phytoplankton (a diverse group existing in two broad communities)
- Mollusca (between 5000-8000 species)
- Echinodermata (estimated 800 extant species, including many rare taxa and type specimens)
- fishes (between 1200 and 2000 species from 130 families, with high species diversity and heterogeneity; includes the Whale Shark *Rhynchodon typus*)
- Seabirds (between 1.4 and 1.7 million seabirds breeding on islands)
- Marine reptiles (including 6 sea turtle species, 17 sea snake species, and 1 species of crocodile)
- Marine mammals (including 1 species of dugong (*Dugong dugon*), and 26 species of whales and dolphins)
- Terrestrial flora: see "Habitats: Islands" and
- Terrestrial fauna, including:
  - Invertebrates (pseudoscorpions, mites, ticks, spiders, centipedes, isopods, phalangids, millipedes, collembolans and 109 families of insects from 20 orders, and large over-wintering aggregations of butterflies); and

  - Vertebrates (including seabirds (see above), reptiles: crocodiles and turtles, 9 snakes and 31 lizards, mammals).

- The integrity of the inter-connections between reef and island networks in terms of dispersion, recruitment, and the subsequent gene flow of many taxa
- Processes of dispersal, colonisation and establishment of plant communities within the context of island biogeography (e.g. dispersal of seeds by air, sea and vectors such as birds are examples of dispersion, colonisation and succession)
- The isolation of certain island populations (e.g. recent speciation evident in two subspecies of the butterfly *Tirumala hamata* and the evolution of distinct races of the bird *Zosterops* spp)
- Remnant vegetation types (hoop pines) and relic species (sponges) on islands
- Evidence of morphological and genetic changes in mangrove and seagrass flora across regional scales; and
- Feeding and/or breeding grounds for international migratory seabirds, cetaceans and sea turtles.

Contain unique, rare and superlative natural phenomena, formations and features and areas of exceptional natural beauty.

The Great Barrier Reef provides some of the most spectacular scenery on earth and is of exceptional natural beauty. The World Heritage values include:

- The vast extent of the reef and island systems which produces an unparalleled aerial vista
- Islands ranging from towering forested continental islands complete with freshwater streams, to small coral cays with rainforest and unvegetated sand cays
- Coastal and adjacent islands with mangrove systems of exceptional beauty
- The rich variety of landscapes and seascapes including rugged mountains with dense and diverse vegetation and adjacent fringing reefs
- The abundance and diversity of shape, size and colour of marine fauna and flora in the coral reefs
- Spectacular breeding colonies of seabirds and great aggregations of over-wintering butterflies; and
- Migrating whales, dolphins, dugong, whale sharks, sea turtles, seabirds and concentrations of large fish.

Provide habitats where populations of rare and endangered species of plants and animals still survive.

The Great Barrier Reef contains many outstanding examples of important and significant natural habitats for in situ conservation of species of conservation significance, particularly resulting from the latitudinal and cross-shelf completeness of the region. The World Heritage values include:

- Habitats for species of conservation significance within the 77 broad-scale bioregional associations that have been identified for the property and which include:
  - Over 2900 coral reefs (covering 20 055km2) which are structurally and ecologically complex

- Large numbers of islands, including:
- 600 continental islands supporting 2195 plant species in 5 distinct floristic regions
- 300 coral cays and sand cays
- Seabird and sea turtle rookeries, including breeding populations of green sea turtles and Hawksbill turtles; and
- Coral cays with 300-350 plant species in 2 distinct floristic regions
- Seagrass beds (over 5000km squared) comprising 15 species, 2 endemic
- Mangroves (over 2070km squared) including 37 species
- Halimeda banks in the northern region and the unique deep water bed in the central region

* Large areas of ecologically complex inter-reefal and lagoonal benthos; and
* Species of plants and animals of conservation significance.

Appendix B A summary of previous studies examining salinity tolerances of a range of marine fish and invertebrates.

Common Name	Species Name	Distribution & Habitat	Salinity Tolerance (PSU=ppt)	Comment	Source
Fish					
Spotted Seatrout larvae	Cynoscion nebulosus	Western Atlantic. Estuaries and shallow marine waters over sand bottoms, often with seagrass beds.	42.5	This is a minimum tolerance range for marine spawned fish larvae. The species belongs to the Family Sciaenidae which includes species found in Port Curtis.	Banks et al. (1991)
Sargo	Anisotremus davidsonii	Eastern Central Pacific Coastal waters - rocky reefs and occasionally over sandy bottoms.	41	Based on maximum salinity within species distribution. The species belongs to the Family Haemulidae which includes species found in Port Curtis.	Black (1988)
Striped mullet	Mugil cephalus	Cosmopolitan in coastal waters of the tropical and subtropical zones of all seas.	38	Based on maximum salinity within species distribution. This species occurs in Port Curtis.	Walker (1961)
Sea Bream juvenile	Pagrus major	Northwest Pacific. 0–50m deep, often on rough grounds (also on softer bottoms and reefs). Juveniles in shallows.	45	Incipient lethal salinity occurred at 50ppt. No avoidance of saline waters occurred at less than 40ppt. They entered often at 45 ppt. At 50ppt, individuals stayed only several tens of seconds. Species of the Family	Iso et al. (1994)

Common Name	Species Name	Distribution & Habitat	Salinity Tolerance (PSU=ppt)	Comment	Source
				occur in Port Curtis	
Flounder eggs and larvae	Pleuronectes yokohamae	Northwest Pacific Inhabits sandy and muddy bottoms in coastal areas.	50	Slight delay of development at 50-55ppt. Incipient lethal salinity occurred at 70ppt for eggs and 50ppt for larvae	Iso et al. (1994)
Crustaceans					
Palaemonid shrimp	Palaemon affinis	New Zealand. Several marine habitats where sheltered from wave action and strong tidal currents (also in rock pools).	43	High survival (>75%)	Kirkpatrick and Jones (1985)
Crab larva	Pagurus criniticornis	Western Atlantic. Gulf of Mexico to Argentina. Brazil. Intertidal and shallow sub-tidal. Mud and sand substrates.	55	Salinity influenced temperature tolerance with thermal limits being greater at 25 and 35 than at 45.	Blaszkowsi & Moreira (1986)
Florida Stone Crabs	Menippe mercenaria				
	Along the Gulf Coast of USA. Estuaries and inlets. High salinity areas, bays, and along jetties. Variety of bottom types, especially oyster reefs.	40	Juvenile survival at these salinities was 100%.	Brown et al. (1992) 1	
Lesser Blue Crab (juveniles)	Callinectes similis	Atlantic coast of USA, northwestern Florida through Gulf of Mexico to Yucatan, Jamaica, Colombia. Near	45	21 day LC50 values were 2.6 and 60.8 at low and high salinities, respectively.	Guerin & Stickle (1997)

Common Name	Species Name	Distribution & Habitat	Salinity Tolerance (PSU=ppt)	Comment	Source
		shore over sand and mud bottoms.			
Gammerid amphipods	Not specified	Widely distributed	59	Maximum range. Species occur in Port Curtis	Grosse and Pauley (1989)
Amphipod	Rhepoxynius abronus	North American Pacific coast. Also sub- and intertidal in estuaries of Oregon and Washington. Predominantly sub-tidal.	43	Tolerant to at least 43ppt.	SCCWRP (1994)
Ghost shrimp	Neotrypaea californiensis	Alaska to Baja California.			
Intertidal. Burrows in sand or mud	41	Species of the Family occur in the Port Curtis area.	Hornig et al. (1989)		
Mysid crustaceans	Not specified		40	Survive salinities to at least 40. Species occur in Port Curtis.	Graham (2005)
Copepod	Gladioferens imparipes	Swan River estuary, WA. Greater distribution unknown.	39.9	21 day copepod reproduction EC50 ecotoxicology test for Perth Desalination Plant	Woodworth (2006)
Molluscs					
Scallop	Pecten fumatus	Australian species (WA to central Qld, including Tasmania) Sand, 0-80m depth.	40	Occurs in the Port Curtis region.	Nell and Gibbs (1986)
Pipi (clam)	Plebidonax deltoides	Australian species (east coast)			

Common Name	Species Name	Distribution & Habitat	Salinity Tolerance (PSU=ppt)	Comment	Source
Burrows in sand.	45	Occurs in the Port Curtis region.	Nell and Gibbs (1986)		
Blue mussel	Mytilus edulis	Australian species (WA to NSW and Tas). Found worldwide in most polar and temperate waters. Intertidal and sheltered and moderately exposed reef, wood pylons, 0-15m.	45	Species of this genus occur in the Port Curtis region	Nell and Gibbs (1986)
Sydney cockle	Anadara trapezia	Australian species (NSW, Qld, Tas, Vic, WA) Intertidal in mud and sand.	45	Species occurs in Port Curtis.	Nell and Gibbs (1986)
Red abalone	Haliotis rufescens	Central British Columbia to Baja California Predominantly sub-tidal, 20-40m (up to 180m). Also intertidal. Rocky open coasts.	40	No mortality at salinities up to 40 after 19 days.	Le Page (2005)
Soft Clam juveniles	Tapes (Ruditapes) philippinarum	Native to Japan. Introduced to France. Intertidal brackish waters. Burrows in sand or muddy gravel, up to 4m.	60	Siphon not protruded at 60-70ppt. At <50ppt no effect was observed. Incipient lethal salinity occurred at 60ppt.	Iso et al. (1994)
Echinoderms					
Sea urchin eggs	Strongylocentrotus purpuratus	Pacific coast (Alaska to Mexico). Low intertidal zone. Thrives in strong wave action.	38.5	Reduction in larval development at 38.5ppt.	SCCWRP (1994)

Common Name	Species Name	Distribution & Habitat	Salinity Tolerance (PSU=ppt)	Comment	Source
Sand dollar	Dendraster excentricus	Pacific ocean (southern Alaska to Mexico). Sandy bottoms of sheltered bays (intertidal and sub-tidal) and open coastal areas (sub-tidal just beyond the break zone).	40	No mortality at salinities up to 40 after 19 days	Le Page (2005)
Corals					
Various reef-building Corals	Porites lutea P. australiensis, Galaxea sp., and Goniastrea pectinata	P. lutea and australiensis: Back reef margins, lagoons and fringing reefs.	39	Growth was significantly lower at salinities higher than 43, although zooxanthellae density among corals did not differ between salinities.	Nakano et al. (1997)
Marine Plants					
Giant kelp	Macrocystis pyrifera	Pacific coast of north America. Australia (Tasmania) Less than 40m depth, less than 20oC, hard substrate.	43	Tolerant to at least 43.	SCCWRP (1994)
Unicellular alga	Nitzschia closterium	Widely distributed in Australian waters	53.8	72 hour microalgal EC50 ecotoxicology test for Perth Desalination Plant	Woodworth (2006)
Worms					
Nematode worms	Not specified	Not specified	40	Survive salinities to at least 40.	Graham (2005)